ISSN: 0001-5113
AADRAY

ACTA ADRIAT,
40 (1): 37-64 , 1999

UDC: 594.587 (262.3)
Original scientific paper

# Kill of benthic organisms as a response to an anoxic state in the northern Adriatic (a critical review)

Ante ŠIMUNOVIĆ[1], Corrado PICCINETTI[2] and Mira ZORE-ARMANDA[1]

[1] *Institute of Oceanography and Fisheries, P.O. Box 500, 21000 Split, Croatia*
[2] *Laboratory for Marine Biology and Fisheries, Fano, Italy*

*Hypoxic and anoxic states, occurring temporarily, count among the problems of the northern Adriatic Sea. In the course of the continental shelf long-term studies (PIPETA programme) of the Adriatic Sea, a drastic deficiency of oxygen concentrations in the bottom layer of the offshore part of the northern Adriatic was recorded in October 1988. Material for this paper was collected during PIPETA cruises (RV, 300 HP). It includes hydrographic and biological data (obtained by trawl and grab). The first signs of newly dead individuals of benthic organisms were recorded at oxygen concentration as low as 1 ml $l^{-1}$. At the stations where the total quantity of dissolved oxygen exceeded 1 ml $l^{-1}$ no signs of dead organisms were found. Fish and cephalopods accumulated in well-aerated area. In 1988 a kill of organisms was recorded within current eddies on the sea bottom rich in organic matter (muddy component). Varying rhythm of sedimentation in the northern Adriatic is affected by the Po River water regime and the velocity of general Adriatic current. Results obtained by grab are illustrative of the varying distribution of animal groups on "mosaic-like" distributed sediment in a very small area. Biological data obtained for different oxygen concentrations at the different profiles and stations in 1988 were compared to the biological data from 1987 and 1991.*

**Key words:** northern Adriatic, hypoxia, anoxia, sediment, trawl, kill of organisms, residual circulation, structural changes, recovery of organisms

## INTRODUCTION

Partial or total kills of benthic organisms caused by anoxic conditions have been recorded and documented on a number of occasions in the northern Adriatic for the last three decades (CRNKOVIĆ, 1974; FEDRA *et al.*, 1976; ZAVODNIK, 1977; DEGOBBIS *et al.*, 1979; STACHOWITSCH, 1984; FAGANELI *et al.*, 1985; OREL *et al.*, 1986; DEGOBBIS, 1989; DEGOBBIS *et al.*, 1990; JAKLIN *et al.*, 1990; DEGOBBIS *et al.*, 1991; HRS-BRENKO *et al.*, 1992; DEGOBBIS *et al.*, 1993; RINALDI, 1993; HRS-BRENKO *et al.*, 1994a, b).

Some authors reported that oxygen deficiency is the reason of the kill of benthic organisms (STEFANON and BOLDIN, 1982; STACHOWITSCH, 1984), as well as the break of normal circulation of the water body below the layers of slimy masses (ZAVODNIK, 1977).

Some authors discussed the tolerant and initial limit of oxygen concentration for benthic organisms (ROSENBERG, 1980; ROSEN-

BERG *et al.*, 1991, TYSON and PERSON, 1991; MALEJ, 1993).

Some of the papers report the time required for the renewal of animal life in bottom biocoenoses (HRS-BRENKO *et al.*, 1994a, b; OTT, 1989) and some describe structural changes within biocoenoses as affected by hypoxic and anoxic states (JAKLIN, 1992; JAKLIN in HRS-BRENKO *et al.*, 1992).

Many authors deal with the mechanisms of hypoxia origin in the bottom layers of the northern Adriatic, in relation to the cause-and effect relations of the individual factors by different methods. Since this paper is not dealing with these problems we do not quote the papers describing the causes of hypoxia occurrence.

During our long-term studies of the continental shelf (PIPETA programme) of the Adriatic Sea, we recorded a drastic drop of oxygen concentrations in the bottom layer of the offshore waters of the northernmost part of the Adriatic in October 1988 (XI th cruise).

Biological data obtained for different oxygen concentrations at different profiles and stations in 1988 were compared to the biological data from January 1987 and January 1991. In addition, some of our own observations, closely related to the specific conditions in the northern Adriatic, are also presented.

Material for this paper was collected during PIPETA cruises (RV, 300 HP). It includes hydrographic and biological data obtained by electronic instrument, trawl and some data obtained by grab (endofauna).

## MATERIAL AND METHODS

Benthic organisms were collected by an Italian type trawl (PICCINETTI, 1972) in January 1987 (Fig. 1), October 1988 (Fig. 2) and January 1991 (Fig. 3). Trawling speed was about 3.5 Nm per hour. Two successive trawl hauls were performed at each station. Data per stations are given as the mean value of two hauls. Abundance indicators per each individual species were expressed in kilograms as a quantity caught in unit time - an hour. During sampling it was attempted to keep the net characteristics constant. The arrows in Figs. 1, 2 and 3 show the first towing direction while the length of arrows show the distance per trawling time. The second towing was frequently performed along the same distance but in the opposite direction.

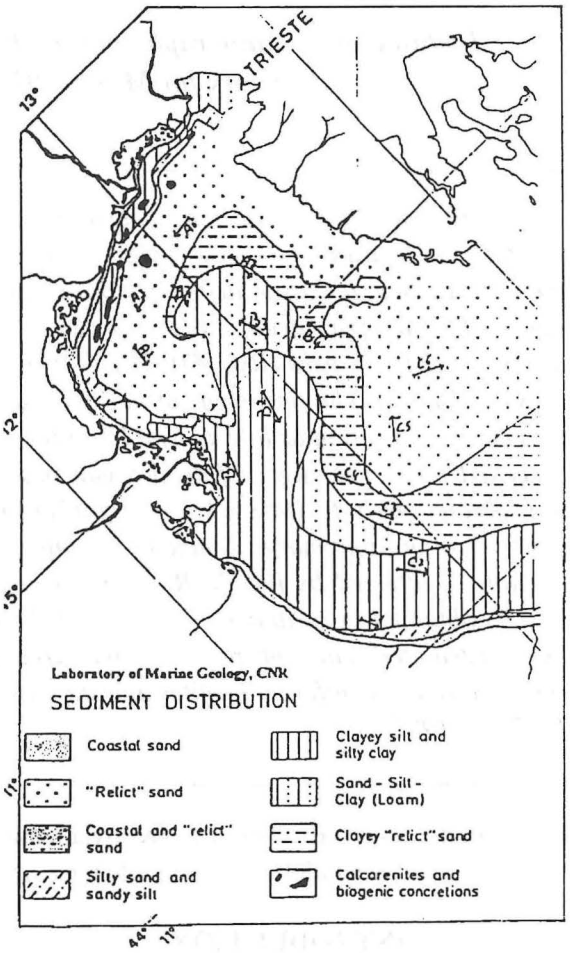


*Fig. 1. Stations of PIPETA Expedition 1987 (January), plotted on the map of sediment distribution (after Laboratory of Marine Geology, CNR, Bologna)*

Material for endofaunal data was collected by grab in May and November 1982. Three successive samples were taken at each station. Van Veen grab of 0.1 $m^2$ was used (CASALI *et al.*, prepared for publication). The data refer to a surface of 1 sq m.

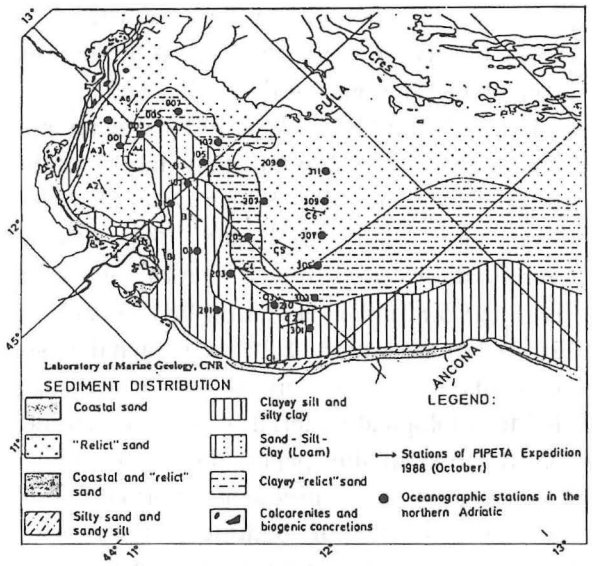


*Fig. 2. Stations of PIPETA Expedition 1988 (October) and oceanographic stations (Precali, 1987), plotted on the map of sediment distribution (after Laboratory of Marine Geology, CNR, Bologna)*

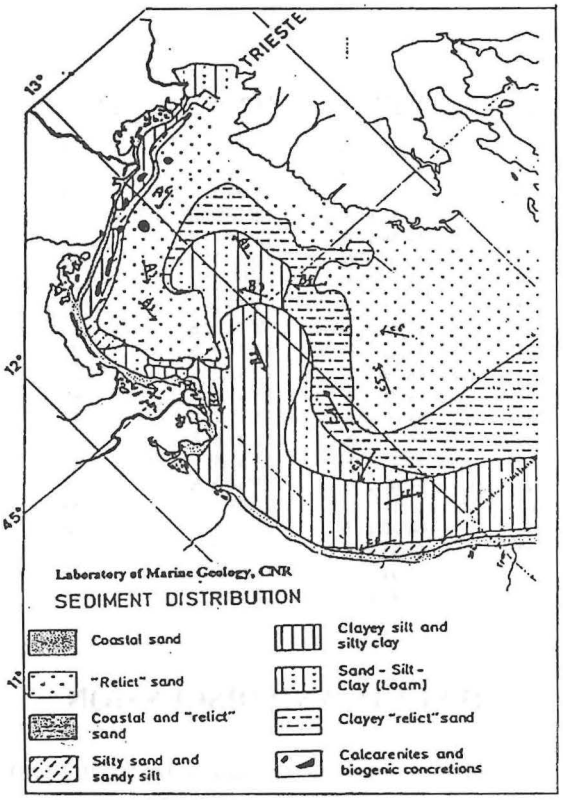


*Fig. 3. Stations of PIPETA Expedition 1991 (January), plotted on the map of sediment distribution (after Laboratory of Marine Geology, CNR, Bologna)*

Hydrographic data for October 1988 were measured with the electronic instrument: Ocean Seven 201, Idronaut, Milan. All the above mentioned data were collected by the Italian commercial trawler PIPETA (300 HP).

*PIPETA stations, (trawl, grab) October 1988, shown in figure 2, are next:*

| STATION | LATITUDE | LONGITUDE | DEPTH (m) | TYPE OF THE SEDIMENT |
|---|---|---|---|---|
| "A2" | 45°19'21 N | 12°37'10 E | 24-26 | "RELICT" SAND |
| | 45°14'80 N | 12°34'68 E | | |
| "A3" | 45°25'31 N | 12°47'50 E | 24-25 | "RELICT" SAND |
| | 45°23'80 N | 12°45'69 E | | |
| "A4" | 45°19'04 N | 12°52'27 E | 31-31.5 | LOAM |
| | 45°17'61 N | 12°52'55 E | | |
| "A6" | 45°29'00 N | 13°04'97 E | 24-25 | "RELICT" SAND |
| | 45°30'02 N | 13°10'36 E | | |
| "A7" | 45°12'11 N | 13°09'70 E | 36-34 | LOAM |
| | 45°18'30 N | 13°11'07 E | | |
| "B1" | 44°55'08 N | 12°35'98 E | 23-23 | CLAYEY SILT AND SILTY CLAY |
| | 44°49'71 N | 12°31'93 E | | |
| "B2" | 44°55'49 N | 12°53'44 E | 36-38 | CLAYEY SILT AND SILTY CLAY |
| | 44°50'13 N | 12°52'72 E | | |
| "B3" | 45°02'25 N | 13°05'40 E | 37-36 | LOAM |
| | 45°08'65 N | 13°04'84 E | | |
| "B4" | 44°52'22 N | 13°17'29 E | 41-39.5 | CLAYEY "RELICT" SAND |
| | 44°58'73 N | 13°13'04 E | | |
| "C1" | 44°09'89 N | 12°32'46 E | 13-14 | SILTY SAND AND SANDY SILT |
| | 44°06'59 N | 12°38'29 E | | |
| "C2" | 44°15'43 N | 12°47'03 E | 37-44.5 | CLAYEY SILT AND SILTY CLAY |
| | 44°12'07 N | 12°54'00 E | | |
| "C3" | 44°23'45 N | 12°46'12 E | 40-42 | LOAM |
| | 44°22'07 N | 12°53'72 E | | |
| "C4" | 44°32'82 N | 12°54'10 E | 44.5-39 | CLAYEY "RELICT" SAND |
| | 44°36'70 N | 12°49'06 E | | |
| "C5" | 44°29'87 N | 13°10'05 E | 49.5-44.5 | "RELICT" SAND |
| | 44°35'19 N | 13°08'39 E | | |
| "C6" | 44°35'26 N | 13°24'40 E | 49.5-44.5 | "RELICT" SAND |
| | 44°31'98 N | 13°29'09 E | | |

*Oceanographic stations (PRECALI, 1987), shown in figure 2, are next:*

| STATION | LATITUDE | LONGITUDE | DEPTH (m) |
|---|---|---|---|
| 001 | 45°21.1' N | 12°52.0' E | 26 |
| 003 | 45°19.1' N | 13°00.2' E | 31 |
| 005 | 45°18.4' N | 13°08.0' E | 30 |
| 007 | 45°17.0' N | 13°16.0' E | 30 |
| 101 | 44°59.8' N | 12°49.8' E | 31 |
| 103 | 45°01.0' N | 12°59.7' E | 35 |
| 105 | 45°02.0' N | 13°09.3' E | 35 |
| 107 | 45°02.8' N | 13°19.0' E | 36 |
| 108 | 44°45.4' N | 12°45.0' E | 32 |
| 201 | 44°29.5' N | 12°34.0' E | 27 |
| 203 | 44°34.0' N | 12°48.0' E | 36 |
| 205 | 44°38.5' N | 12°01.8' E | 40 |
| 207 | 44°43.0' N | 12°15.7' E | 43 |
| 209 | 44°47.5' N | 12°29.8' E | 43 |
| 210 | 44°20.7' N | 12°51.5' E | 40 |
| 301 | 44°09.2' N | 12°54.0' E | 39 |
| 303 | 44°14.7' N | 13°03.5' E | 53 |
| 305 | 44°20.2' N | 13°12.5' E | 52 |
| 307 | 44°25.7' N | 13°21.7' E | 51 |
| 309 | 44°31.5' N | 13°31.0' E | 41 |
| 311 | 44°37.2' N | 13°40.0' E | 46 |

## RESULTS AND DISCUSSION

Hypoxic and anoxic states, occurring temporarily, count among the problems of the northern Adriatic Sea. In the course of the long-term studies of the continental shelf (PIPETA programme) of the Adriatic Sea, a drastic deficiency of oxygen concentrations in the bottom layer of the stations "A4" (0.97 ml $l^{-1}$), "A7" (1.47 ml $l^{-1}$) and "B3" (1.88 ml $l^{-1}$) was recorded in October 1988. For the other stations of the profiles "A" and "B", which were sampled ("A2", "A3", "A6", "B1", and "B4"), oxygen concentration varied from 2.70 ml $l^{-1}$ at station "B4" and 5.80 ml $l^{-1}$ at station "B1" (Table 1, Fig. 2). For the station "B2" the oxygen data are not available. The "C" profile, which was sampled for biological material, was not taken into consideration in this paper, due to the rather good aeration and consequently normal condition for the life of benthic communities. Oxygen ranged from 5.01 ml $l^{-1}$ to 8.90 ml $l^{-1}$ (Table 1, Fig. 2).

In the Bay of Trieste and the Rijeka Bay CRNKOVIĆ (1974), ŠTIRN *et al.*, (1974) and FEDRA *et al.*, (1976) recorded and documented partial or even total kill of benthic organisms during the "sea water bloom". ŠTIRN and BOLJE (1989) also reported the kill of two species of shells (*Pecten jacobaeus* and

*Table 1. Hydrographic data collected during PIPETA trawl survey expedition in 1988 (October)*

| Station: | A2 | A3 | A4 | A6 | A7 | |
|---|---|---|---|---|---|---|
| Date: | 19.10.88. | 18.10.88. | 18.10.88. | 18.10.88. | 18.10.88. | |
| Depth (m): | 21.20 | 23.60 | 31.60 | 23.20 | 35.50 | |
| $O_2$ (ml $l^{-1}$): | 4.51 | 4.50 | 0.97 | 4.34 | 1.41 | |
| T (°C): | 17.64 | 17.61 | 15.06 | 17.65 | 15.46 | |
| Station: | B1 | B3 | B4 | | | |
| Date: | 19.10.88. | 17.10.88. | 17.10.88. | | | |
| Depth (m): | 25.30 | 36.40 | 40.60 | | | |
| $O_2$ (ml $l^{-1}$): | 5.80 | 1.88 | 2.70 | | | |
| T (°C): | 18.31 | 15.52 | 15.12 | | | |
| Station: | C1 | C2 | C3 | C4 | C5 | C6 |
| Date: | 13.10.88. | 13.10.88. | 13.10.88. | 14.10.88. | 12.10.88. | 11.10.88. |
| Depth (m): | 12.60 | 36.20 | 38.80 | 42.90 | 41.90 | 48.00 |
| $O_2$ (ml $l^{-1}$): | 5.01 | 5.56 | 5.13 | 5.53 | 8.25 | 8.90 |
| T (°C): | 19.46 | 17.14 | 16.64 | 15.63 | 15.71 | 15.60 |

*Chlamys opercularis*) in the Bay of Trieste in autumn 1987. JUSTIĆ (1987, 1988) and JUSTIĆ *et al.*, (1987) tried to argument the hypothesis that the hypoxia occurrence and mass benthic organisms kills were due to the long-term anthropogenetic eutrophication of the northern Adriatic. LEGOVIĆ and JUSTIĆ (1997) connect eutrophication of the northern Adriatic for the reduction of dissolved oxygen concentration in the bottom layer. Discussing the phytoplankton blooms with the appearance of intensive hypoxia in the northern Adriatic, they also presented detailed records of its appearance as well as the organisms mortality. HRS-BRENKO *et al.*, (1994a, b) reported that the summer "sea water bloom" in 1989 was followed by a drastic drop in oxygen at the bottom and kill of organisms in bottom biocoenoses in a rather large part of the offshore northern Adriatic waters. DEGOBBIS *et al.*, (1990) recorded temporarily extreme eutrophication occurrences in the offshore waters of the northern Adriatic accompanied by the kill of benthic organisms due to oxygen deficiency. On the contrary, MALEJ (1993) stated that, with respect to a data series available up to then, the occurrence of hypoxia and anoxia in the Bay of Trieste appeared not to be related to the eutrophication but rather to the combined impact of morphological and hydrographic factors.

It is possible that dissolved oxygen deficiency is generally responsible for the frequent kills of benthic organisms (STEFANON and BOLDIN, 1982; STACHOWITSCH, 1984). Therefore, some authors tried to determine the critical oxygen concentration for benthic species. So, ROSENBERG (1980) observed that the concentration of about 2 ml $l^{-1}$ is the lower tolerance limit for a large number of benthic species and the concentration of 1 ml $l^{-1}$ is critical. The same concentrations and responses of benthic organisms were reported by MALEJ (1993). ROSENBERG *et al.* (1991) examined the limits of tolerance to hypoxia for eight species and found that this limit ranged from 0.5 to 1.0 ml $l^{-1}$, dependently on individual species, within which range they may survive from several days to several weeks. TYSON and PEARSON (1991) reported the oxygen concentrations from 2.0 to 0.2 ml $l^{-1}$ as a hypoxic state in the sea.

During our studies, we recorded the first signs of newly dead specimens of benthic organisms at station "A4" ($O_2$ = 0.97 ml $l^{-1}$) where out of 21 specimens of *Pinna pectinata*, three specimens were dying, of 20 specimens of *Cardium paucicostatum*, 10 had just died, and of 3865 specimens of the species *Chlamys opercularis*, 80 decayed, (Table 3 in Annex). At station "B2" (no oxygen data available) a complete settlement of *Amphiura filiformis* was killed (13.335 kg $h^{-1}$ - trawl). Of other species, we recorded eight alive specimens of *Nephrops norvegicus* and seven dead ones. One specimen of *Pecten jacobaeus* was alive while another was dead. On the rest of the stations of the "A" and "B" profiles, where the total level of dissolved oxygen ranged from 4.1 ml $l^{-1}$ to 5.80 ml $l^{-1}$ we found no signs of kill. So, it may be said that our data conform to the data of the above mentioned authors as to the critical point under which the death of organisms occurs.

It is interesting that the hypoxic area itself is responsible for the accumulation of fish and cephalopods in well aerated areas. The highest accumulations of fish and cephalopods we detected at stations "A6" ($O_2$ = 4.34 ml $l^{-1}$), 59.86 kg $h^{-1}$ and at station "B1" ($O_2$=5.80 ml $l^{-1}$) where out of the total quantity caught (87.09 kg $h^{-1}$) the species *Mullus barbatus* was represented with 54.32 kg $h^{-1}$ (Table 2 in Annex). RINALDI (1993) also reported anoxia in summer 1982, in the area of Emilia-Romagna (the belt from the coast to 4 km offshore) and fish accumulation in the narrow coastal belt of 500 to 800 m widths offshore, which was aerated. After RINALDI (1993) fish accumulated in large quantities in this narrow belt, in fact fish were "imprisoned" there. So, 100 to 200 kg of *Mullus barbatus* could be caught by trawl from this narrow belt in a very short time. With

respect to this fact, we suggest for all fishing activities to be ceased in the northern Adriatic during hypoxia. ŠTIRN and BOLJE (1989) also recommend that during the state of hypoxia all fisheries activities should be forbidden. We can support this suggestion by a variety of reasons. One of them is the protection of the area where the fish has accumulated until its return to the area wherefrom it migrated. Trawling and particularly work with "rapid" during hypoxia make the situation even worse. The problem is that trawl can sweep several sediment types, that is biocoenoses, in a short while. If we take a look of the sedimentary map of the Adriatic (Figs. 1,2,3,4), it may be easily seen that sediment very quickly changes in a relatively small area in relation to the rest of the Adriatic. Thus, species migrate to the areas of unfavorable condition, and die therefore. Similar is applicable to the "rapid", which mixes up sediment layers whereas trawl transfers biological material from one sediment type to another (it is well known that almost all endobionts bury themselves down to 10 cm depth and that any disturbance in that layer causes problems for the species living there).

Two current eddies: the cyclonic one - north of the line of the River Po - Rovinj and the anticyclonic one, south of that line, insert into the overall Adriatic cyclonic system in the northern Adriatic (Fig. 5). Such two-gyre system is induced by the river Po and preferably by bura (NE) wind. Due to the frequency of that wind it was identified in the residual current field, as well (ZORE-ARMANDA and GAČIĆ, 1987). After ARTEGIANI *et al.* (1997) the cyclonic gyre in the surface layer becomes evident in summer and autumn. The present paper deals with these seasons. It may be assumed that the flow is weaker in the center of the eddy. Therefore, the muddy component is well developed there. As shown by Fig. 5, the stations ("A4", "B2"), where the organisms kill occurred, are in the centers of both eddies. Apart from current meter data, such a current field is also shown by sedimentary maps (ZORE-ARMANDA, 1986; ZORE-ARMANDA and VUČAK, 1984). Van STRAATEN (1965) showed how the distribution of sediments was obviously affected by the current direction and speed (Fig. 4).

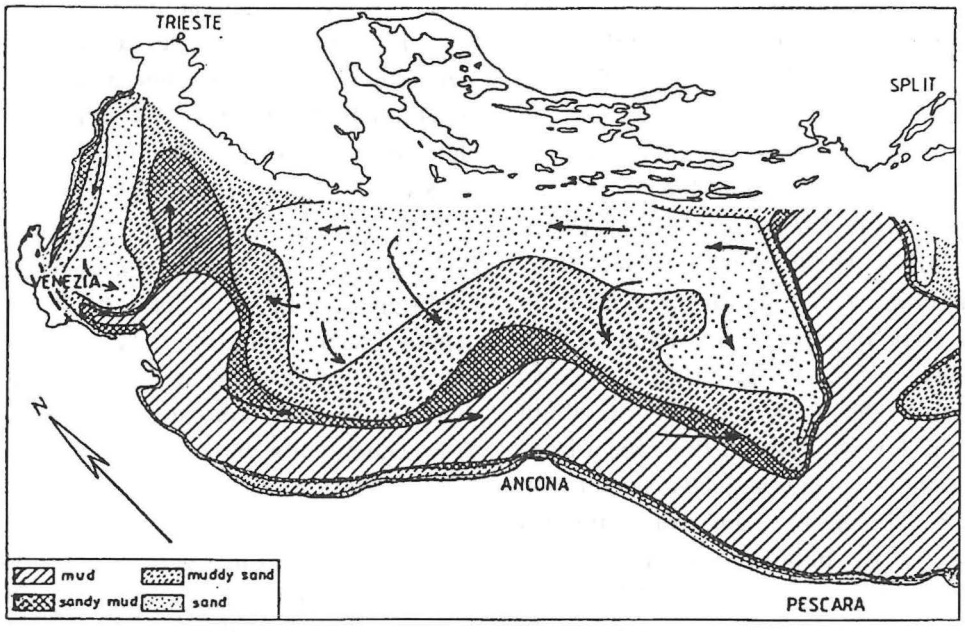


*Fig. 4. Bottom sediment distribution and mean flow directions (after Van STRAATEN, 1965)*


*Fig. 5. Schematic plot of the northern Adriatic residual circulation (after ZORE-ARMANDA and VUČAK, 1984). Stations "A4" and "B2" wherefrom the kill of organisms was recorded, were added*

On this basis, we realized that hypoxia (October 1988) occurred in the northern Adriatic part where two eddies, or closed flow systems, establish in the course of the year. After the sedimentary map (Fig. 2) muddy component is well represented in the area with hypoxia. Therefore, establishing of eddies, minimum flow speed in the flow centers cause the deficiency of dissolved oxygen as a result of pronounced stagnation of water and consequently the kill of organisms on a substrate rich in organic matter (muddy component). From the rough positioning of permanent oceanographic stations, PRECALI (1987) from the Institute "Ruđer Bošković", Center for Marine Research, Rovinj, on the sedimentary map (Fig. 2) it appears that hypoxia and anoxia occur in the same area. HRS-BRENKO *et al.*, (1992) state that anoxic condition, in November 1989, brought to mortality of almost all sedentary organisms on 005, 007 and 107 stations (Fig. 2). DEGOBBIS *et al.*, (1991) also state that in November 1989, anoxia was observed with mass mortality of benthic organisms at the stations 005, 007 and 107, and partly at the stations 003, 105 and 103 (Fig. 2). Hypoxia and anoxia were also recorded from the Bay of Trieste, Venice and Rijeka Bay on several occasions (CRNKOVIĆ, 1974; ŠTIRN *et al.*, 1974; FEDRA *et al.*, 1976; ZAVODNIK, 1977; STACHOWITSCH, 1984; FAGANELI *et al.*, 1985; OREL *et al.*, 1989). OREL *et al.*, (1989) concluded that some parts of sandy bottoms along the Emilia-Romagna coastline, the area of Marche, some parts of muddy-detritic bottoms of the territorial waters in the Bay of Trieste and the whole central part of the Venetian Bay (relict sand) appear to be the most suitable areas (as the consequence of reduction in oxygen concentrations). It seems that the problem is in the combined effect of two factors. Under the conditions of poor water circulation, hypoxia occurs primarily on muddy bottoms and spreads partly to the adjacent areas overloaded by organic substances.

From the data in the literature available for the offshore part of the northern Adriatic, it wasn't possible to establish it, or how much hypoxia occurs at the sandy bottoms, in general. Therefore, in the north-western part of the northern Adriatic (Figs. 1, 2, 3), were, after VATOVA (1949), the well developed biocoenoses of coarse sands and tiny gravel is affected by bottom currents, it would be an interesting to establish if this area is endanger by hypoxia.

Some literature data report on the time required for the renewal of animal species or benthic communities in areas under hypoxia. So, HRS-BRENKO *et al.* (1992) found that the renewal of a shellfish population, after the anoxia in autumn 1989, was relatively rapid. The number of species gradually increased approaching the summer. Some species occurred with a large number of individuals and almost all the species, which were present earlier, returned. HRS-BRENKO *et al.* (1994a, b) also reported that the summer "bloom" in 1989 was followed by a drastic reduction of oxygen

at the bottom and kill of organisms of the bottom biocoenoses in a rather large part of the offshore waters of the northern Adriatic. A year after the kill almost all the species were recorded. Only the density of individual species was different. OTT (1989) states that the recovery from anoxia is primarily dependent on the extent of affected area. Smaller parts are faster recovered by immigration of adult animals. Larger areas take long time to recover, particularly those dominated by varying and structurally complex epifauna. This author believes that it takes more than five years for such an area to recover from anoxia under totally undisturbed conditions. After our data, obtained by trawl, the problem of the percentage and the rate of recovery of damaged benthic biocoenoses, affected by anoxia, appears to be very complex. We have come to this conclusion from a variety of reasons. It is well known that the depth and the type of bottom are very important factors affecting the distribution of benthic organisms. As to the northern Adriatic, the sediment is mosaic-like distributed so that there are numbers of boundaries between two sediment types. On the other hand, the sedimentation rhythm is variable in the northern Adriatic due to the water regime of the Po River and the speed of the general Adriatic flow. Therefore, the northern Adriatic sediment is rather compact in summer and much looser in winter (personal observations). OREL *et al.* (1989) observed the variation of sedimentation rhythm characteristic of the central part of the Venetian Bay which, as they stated, was affected by the water regime of the Po River. COLANTONI *et al.* (1979) also reported on the considerable sand and mud input of the Po River, on the distribution of sediment in the wider area of the Po River, and, among the other things, on the causes of partial change in the biotope. COLANTONI (1972, 1978) presented the mosaic disposition of sediments in the northern Adriatic, respectively in the area of Po River, In addition, it may be said that, with respect to the mosaic-like distribution of sediment in the northern Adriatic with a large numbers of boundaries between two sediment types, some difficulties occur in the interpretation of material collected from fixed stations due to the questionable ship positioning (quite a small shift to the right or left may lead to the change of depth or to a partial change of sediment type). This may later cause both qualitative and quantitative errors when comparing the data. Vessel positioning at sampling was mentioned as a problem also by ZAVODNIK (1993).

JAKLIN (1992) and JAKLIN in HRS-BRENKO *et al.* (1992) reported that in recent years, at the end of summer and in autumn, rather frequent anoxia and hypoxia cause structural changes in the biocoenoses. They stated that the relationships between individual groups within biocoenoses change after mass kills. So the Mollusca group (Bivalvia and Gastropoda) became dominant at the level of macrofauna with 80% specimens in the Po River area in 1990 and 1991, whereas it was less represented than Polychaeta and Echinodermata in 1982. During our field trip in May 1982, after the data collected by grab (CASALI *et al.* - prepared for publication), systematic groups: Annelida (Polychaeta), Mollusca (Bivalvia) were dominant north of the Po River, and Annelida (Polychaeta), Mollusca (Gastropoda) and Echinodermata east of the Po River. At stations south of the Po River, Mollusca (Bivalvia) prevailed on coastal stations and Annelida (Poychaeta) in a wider area. Samples collected in November of the same year show similar distribution of above mentioned dominant groups. These results obtained by grab are illustrative of the diversity of animal group distribution on the "mosaic- like" distributed sediments in a very small area.

Comparing our data, obtained by trawl in 1988 (January and October) and 1991 (January), and taking into account everything mentioned above, it may be said that a migration of fish groups and cephalopods to an area richer in oxygen (Table 2 in Annex) was observed. As to the rest of the bottom fauna,

some qualitative and quantitative changes were recorded (Table 3 in Annex). However, the level of the consequences to benthic biocoenoses, due to anoxia, could not be ascertained from the extent of these changes. It is, however, undoubtful that anoxia causes adverse effects in areas where it occurs. However, as it appears from the literature data, the ecosystem of the northern Adriatic still manages to keep equilibrium in this respect with no long-term consequences.

## CONCLUSIONS

During PIPETA cruise in the northern Adriatic in October 1988, hypoxic state (oxygen concentrations between 0.97 to 1.88 ml $l^{-1}$) has been observed at stations "A4", "A7" and "B3". At the rest of stations the values of oxygen concentration were between 2.70 ml $l^{-1}$ to 5.80 ml $l^{-1}$. At the same time at the stations "A4" and "B2" the mortality of benthic organisms has been found. For stations "B2" oxygen data were not available. It is assumed that hypoxic state was the reason for the mortality. Current system was analyzed as well, and it was observed that both stations, where mortality appeared ("A4" and "B2") are located in the center of current eddies where muddy component is important due to the lower level of circulation.

The problem of mortality is rather complicated and from that respect, it may be strongly recommended to monitor the northern Adriatic. During the hypoxia state any fishing should be forbidden.

## REFERENCES

ARTEGIANI, A., D. BREGANT, E. PASCHINI, N. PINARDI, F. RAICICH and A. RUSSO. 1997. The Adriatic Sea General Circulation. Part II: Baroclinic Circulation Structure. Journal of physical oceanography, 27 (8): 1515-1532.

COLANTONI, P. 1972. Ricerche sui molluschi dei fondali antistanti il delta del Po. Giornale di Geologia, 38 (2): 513-532.

COLANTONI, P. 1978. La distribuzione dei Molluschi in relazione alle caratteristiche dei fondali dell'Alto Adriatico. In: I Molluschi Bivalvi, produzione e controllo igienico-sanitario. Atti del I Incontro sulle Risorse Marine 86, 91, Castrocaro Terme (Forli).

COLANTONI, P., P. GALLIGNANI and R. LENAZ. 1979. The sediments of the Po river delta and adjacent continental shelf. Rapp. Comm. int. Mer Médit., 25/26 (2a): 127-128.

CRNKOVIĆ, D. 1974. Problematika eksploatacije biocenoza pomičnog substrata cirkalitorala u priobalnom području sjevernog Jadrana. Vijesti Muzeal. Konzerv. Hrvatske, 23: 87-92.

DEGOBBIS, D. 1989. Increased eutrophication in the northern Adriatic Sea. Mar. Poll. Bull., 20: 452-457.

DEGOBBIS, D., N. SMODLAKA, I. POJED, A. ŠKRIVANIĆ and R. PRECALI. 1979. Increased eutrophication of the northern Adriatic Sea. Mar. Poll. Bull., 10: 298-301, Oxford.

DEGOBBIS, D., N. SMODLAKA, R. PRECALI and I. IVANČIĆ. 1990. Posljedice izrazite eutrofikacije sjevernog Jadrana u obalnom moru Istre 1989. godine. Pomorski zbornik, 28: 611-629.

DEGOBBIS, D., I. IVANČIĆ, R. PRECALI and N. SMODLAKA. 1991. Neuobičajene oceanografske prilike u sjevernom Jadranu tokom 1989. godine. 1. Oceanografska svojstva, ciklus hranjivih soli i jesenska pridnena anoksija. Hidrografski godišnjak 1989: 27-47.

DEGOBBIS, D., A. TRAVIZI and A. JAKLIN. 1993. Meccanismi di formazione di strati di fondo ipossici e anossici nel bacino dell'Alto Adriatico settentrionale e relazioni delle comunità bentoniche. In: Orel, G., Fonda Umani, S. and F. Aleffi, Ipossie e anossie di fondali marini. L'Alto Adriatico e il Golfo di Trieste. Regione Autonome Friuli-Venezia Giulia, Ricci, Trieste: 57-62.

FAGANELI, J., A. AVČIN, N. FANUKO, A. MALEJ, V. TURK, P. TUSNIK, B. VRISER and A. VUKOVIĆ. 1985. Bottom layer anoxia in the central part of the Golf of Trieste in the summer of 1983. Mar. Poll. Bull., 16 (2): 75-78.

FEDRA, K., E. M. ÖLSCHER, C. SCHERÜBEL, M. STACHOWITSCH and R. S. WURZIAN. 1976. On the ecology of a north Adriatic bentic community: Distribution, standing crop, and composition of the macrobenthos. Mar. Biol., 38: 129-145.

HRS-BRENKO, M., A. JAKLIN, E. ZAHTILA and D. MEDAKOVIĆ. 1992. Školjkaši i nestašice kisika u sjevernom Jadranu. Pomorski zbornik, 30: 581-597.

HRS-BRENKO, M., D. MEDAKOVIĆ, Ž. LABURA and E. ZAHTILA. 1994a. Bivalve recovery after a mass mortality in the autumn of 1989 in the northern Adriatic Sea. The Fifth Congress of Croatian Biologist. Croatian Biological Society. Proceedings of abstracts, Zagreb: 322-323.

HRS-BRENKO, M., D. MEDAKOVIĆ, E. LABURA and E. ZAHTILA. 1994b. Bivalve recovery after a mass mortality in the autumn of 1989 in the northern Adriatic Sea. Period. biol., 96 (4): 455-458.

JAKLIN, A. 1992. Structural change in a North Adriatic sediment macrofauna. Rapp. Comm. int. Mer Médit., 33: p. 348.

JUSTIĆ, D. 1987. Long-term eutrofication of the northern Adriatic Sea. Mar. Poll. Bull., 18 (6): 281-284.

JUSTIĆ, D. 1988. Trend in the transparency of the northern Adriatic Sea 1911-1982. Mar. Poll. Bull., 19 (1): 32-35.

JUSTIĆ, D., T. LEGOVIĆ and L. ROTTINI-SANDRINI. 1987. Trends in oxygen content 1911-1984 and occurrence of benthic mortality in the northern Adriatic Sea. Estuar. Cost. Shelf Sci., 25: 435-445.

LEGOVIĆ, T. and D. JUSTIĆ. 1997. When do phytoplankton blooms cause the most intense hypoxia in the northern Adriatic Sea?. Oceanologica Acta, 20 (1): 91-99.

MALEJ, A. 1993. Ipossie e anossie nel Golfo di Trieste. In: Orel, G., Fonda Umani, S. and F. Aleffi. Ipossie e anossie di fondali marini. L'Alto Adriatico e il Golfo di Trieste. Regione Autonome Friuli-Venezia Giulia, Ricci, Trieste: 63-77.

OREL, G., E. VIO, M. PRINCI, D. Del PIERO and F. ALEFFI. 1986. Stati di anossia dei fondali, popolamenti bentonici e pesca. Nova Thalassia, 8, suppl. 3: 267-280.

OREL, G., E. VIO and F. ALEFFI. 1989.Biocenosi bentoniche e loro modificazioni in seguito a stress anossici. In: L'eutrofizzazione nel Mare Adriatico. Atti del Convegno nazionale, Ancona, 4 Aprile 1989: 59-63.

OTT, J. 1989. Changes in the North Adriatic Benthos. Atti del Convegno: Lo stato di salute dell'Adriatico - problemi e prospetive, Urbino, 23 e 24 maggio 1989: 75-83.

PICCINETTI, C. 1972. FAO Catalogue of Fishing gear disigns, London: p. 42.

PRECALI, R. 1987. 2. Monitoring sjevernog Jadrana. In: Precali, R., Z. Konrad (Editors). Opći program za Jadransko more Jugoslavensko-talijanske mješovite komisije za zaštitu Jadranskog mora i obalnih područja od

zagađenja, Izvještaj o radu za 1986. godinu, Rovinj: 7-9.

RINALDI, A. 1993. Ipossie ed anossie nelle acque costiere dell'Adriatico Nord-occidentale. Loro evaluzione e conseguenze sull'ecosistema bentonico. In: Orel, G., Fonda Umani, S. and F. Aleffi. Ipossie e anossie di fondali marini. L'Alto Adriatico e il Golfo di Trieste. Regione Autonome Friuli-Venezia Giulia, Ricci, Trieste: 52-57.

ROSENBERG, R. 1980. Effect of oxygen deficiency on bentonic macrofauna. In: Freeland, J. H., Farmer, D. M., C. D. Levings (Editors). Fjord oceanography plenum. Publ. Corp., New York: 499-514.

ROSENBERG, R., B. HELLMAN and B. JOHANSSON. 1991. Hypoxic tolerance of marine benthic fauna. Mar. Ecol. Prog. Ser. 79: 127-131.

STACHOWITSCH, M. 1984. Mass mortality in the Gulf of Trieste: The course of community destruction. Mar. Ecol., 5 (3): 243-264.

STEFANON, A. and A. BOLDIN. 1982. The oxygen crisis of the northern Adriatic Sea waters in late fall 1977 and its effects on benthic communities. In: Blanchard, J., Mair, J. and I. Morrison (Editors). Proc. 6th Symp. Conf. Mond. des Activités Subaquatiques, Nat. Env. Res. Coun.: 167-175.

ŠTIRN, J., A. AVČIN, J. CENCELJ, M. DORER, S. GOMIŠČEK, S. KVEDER, A. MALEJ, D. MEISCHNER, I. NOŽINA, J. PAUL and P. TUŠNIK. 1974. Pollution problems of the Adriatic Sea. Rev. Int. Oceanogr. Méd., 35/36: 21-78.

ŠTIRN, J. and A. BOLJE. 1989. Fondi pridnenih rib in drugih užitnih organizmov obalnih voda SFRJ v Tržaškem zalivu. Droga Portorož in Inštitut za biologijo Univerze v Ljubljani, Morska biološka postaja Piran: p. 30 i p. 34.

TYSON, R. and T. H. PEARSON. 1991. Modern and ancient Continental shelf anoxia: an overview. In: Tyson, R. V. and T. H. Pearson (Editors). Modern and Ancient Continental Shelf Anoxia. Geol. Soc. Special Publ., 58: 1-24.

VAN STRAATEN L. M. J. U. 1965. Sedimentation in the north-western part of the Adriatic Sea, submarine geology and geophysics. In: Proc. 17th Symp. of the Colston Research Society, Whittard and Bradshaw, Colston papers, 17: 143-160.

VATOVA, A. 1949. La fauna bentonica dell'Alto e Medio Adriatico. Nova Thalassia, 1 (3): 1-110.

ZAVODNIK, D. 1977. Benthic communities in the Adriatic Sea: Reflects of pollution. Thalassia Jugosl., 13: 413-422.

ZAVODNIK, D. and A. JAKLIN. 1993. 2.12. Životne zajednice morskog dna. U: Precali, R. and Z. Konrad (Editors). Opći program bilateralne suradnje s Italijom na zaštiti Jadranskog mora i obalnih područja od zagađenja. Izvještaj o radu za 1993. godinu, Rovinj: 83-105.

ZORE-ARMANDA, M. 1986. Karakteristike strujanja istočno-jadranskog priobalja. Pomorski zbornik, 24: 384-406.

ZORE-ARMANDA, M. and M. GAČIĆ. 1987. Effects of bura on the circulation in the North Adriatic. Annales Geophysicae, 5B (1): 93-102.

ZORE-ARMANDA, M. and Z. VUČAK. 1984. Some properties of the residual circulation in the northern Adriatic. Acta Adriat., 25 (1/2):101-117.

Accepted: 14 May 1999

# Refleksija anoksičnog stanja na ugibanje bentoskih organizama u sjevernom Jadranu (kritički osvrt)

Ante ŠIMUNOVIĆ[1], Corrado PICCINETTI[2] i Mira ZORE-ARMANDA[1]

[1] *Institut za oceanografiju i ribarstvo, P.P. 500, 21000 Split, Hrvatska*

[2] *Laboratorij za biologiju mora i ribarstvo, Fano, Italija*

## SAŽETAK

Među probleme sjevernog Jadrana ubrajaju se hipoksična i anoksična stanja, koja se povremeno javljaju. Tijekom dugogodišnjih istraživanja kontinentalnog šelfa (program PIPETA) Jadranskog mora, u listopadu 1988. godine zabilježeno je drastično sniženje koncentracije kisika u pridnenom sloju pučinskoga dijela sjevernog Jadrana. U ovom radu su korišteni biološki podaci (dobiveni povlačnom mrežom i grabilom) programa PIPETA. Podaci su prikupljeni komercijalnim brodom m/b PIPETA (300 Ks). Prvi znakovi svježe uginulih primjeraka bentoskih organizama primijećeni su kada je koncentracija kisika pala na oko 1 ml $l^{-1}$. Na onim postajama profila "A" i "B" gdje se ukupna količina otopljenoga kisika kretala iznad 1 ml $l^{-1}$ nisu primijećeni nikakvi znakovi ugibanja. Skupine riba i glavonožaca su se koncentrirale u dobro prozračenome području. U 1988. godini unutar strujnih vrtloga došlo je do ugibanja organizama na podlozi bogatoj organskim sadržajem (muljevita komponenta). Promjenljivi ritam taloženja u sjevernom Jadranu zavisi o vodnom režimu rijeke Po kao i brzini opće jadranske struje. Rezultati dobijeni grabilom ilustriraju raznolikost rasporeda životinjskih skupina na "mozaično" raspoređenom sedimentu, na jednom vrlo malome području. U okviru različitih vrijednosti kisika, nađenih na postajama i profilima u listopadu 1988. godine, dobijeni biološki podaci uspoređeni su s biološkim podacima iz 1987. i 1991. godine.

# ANNEX

*Table 2. Quantitative (kg h$^{-1}$) list of the species collected during PIPETA trawl survey expedition in 1988 (January, October) and 1991 (January)*

**A2**

| Station: | A2 | A2 | A2 |
|---|---|---|---|
| Date: | 12.01.88. | 19.10.88. | 09.01.91. |
| Depth (m): | 25 | 24-26 | 28 |
| Species list: | kg h$^{-1}$ | kg h$^{-1}$ | kg h$^{-1}$ |
| *Squilla mantis* | - | 0.191 | - |
| *Loligo vulgaris* | 0.231 | 0.443 | 0.106 |
| *Alloteuthis media* | - | - | 0.106 |
| *Sepia officinalis* | 0.369 | 0.128 | 1.024 |
| *Eledone moschata* | - | 5.513 | 4.764 |
| *Mustelus mustelus* | - | 0.788 | - |
| *Squalus acanthias* | - | - | 0.071 |
| *Engraulis enchrasicholus* | 0.036 | - | - |
| *Merluccius merluccius* | - | 0.015 | - |
| *Merlangius merlangus* | 0.092 | - | 0.212 |
| *Trisopterus minutus capelanus* | 0.092 | 1.932 | 3.530 |
| *Zeus faber* | - | - | 0.106 |
| *Cepola rubescens* | - | - | 0.035 |
| *Trachurus mediterraneus* | - | 0.675 | 1.800 |
| *Atherina boyeri* | - | - | 0.706 |
| *Mullus barbatus* | 0.018 | 2.250 | 0.012 |
| *Pagellus erythrinus* | - | 0.011 | - |
| *Gobius niger* | - | - | 0.035 |
| *Gobius quadrimaculatus* | - | - | 0.759 |
| *Callionymus maculatus* | - | - | 0.005 |
| *Blennius ocellaris* | - | - | 0.021 |
| *Trigla lucerna* | - | 0.431 | 0.353 |
| *Arnoglossus thori* | - | - | 0.016 |
| *Solea vulgaris* | - | - | 1.200 |
| *Solea kleinii* | - | 0.045 | 0.035 |
| *Solea lutea* | 0.046 | - | - |
| Total: | 1.345 | 12.422 | 14.900 |
| Number of species: | 7 | 12 | 20 |

**A3**

| Station: | A3 | A3 | A3 |
|---|---|---|---|
| Date: | 12.01.88. | 18.10.88. | 09.01.91. |
| Depth (m): | 25 | 24-25 | 26 |
| Species list: | kg h$^{-1}$ | kg h$^{-1}$ | kg h$^{-1}$ |
| *Loligo vulgaris* | 1.938 | 3.000 | 0.758 |
| *Alloteuthis media* | 0.110 | - | 1.026 |
| *Sepia officinalis* | 0.369 | 0.222 | 0.126 |
| *Sepiola sp.* | - | - | 0.379 |
| *Eledone moschata* | 10.338 | 6.222 | 8.842 |
| *Sardina pilchardus* | 0.055 | - | - |
| *Engraulis encrasicholus* | 0.050 | - | - |

*Table 2. cont'd*

| | | | |
|---|---|---|---|
| *Conger conger* | - | - | 1.011 |
| *Merlangius merlangus* | 0.276 | - | - |
| *Trisopterus minutus capelanus* | - | - | 0.107 |
| *Cepola rubescens* | - | - | 0.107 |
| *Trachurus mediterraneus* | 1.827 | 2.222 | 2.084 |
| *Mullus barbatus* | - | 6.889 | 0.013 |
| *Pagellus erythrinus* | - | 0.200 | - |
| *Trachinus draco* | 0.369 | - | - |
| *Atherina boyeri* | - | - | 0.025 |
| *Gobius quadrimaculatus* | 0.830 | - | 0.505 |
| *Gobius niger* | - | - | 0.253 |
| *Boops boops* | - | 0.267 | - |
| *Callionymus maculatus* | - | - | 0.253 |
| *Trigla lyra* | - | 1.444 | - |
| *Platichthys flesus* | 0.036 | - | - |
| *Trigla lucerna* | - | - | 0.221 |
| *Arnoglossus thori* | - | - | 0.006 |
| *Arnoglossus kesslerii* | - | - | 0.025 |
| *Solea kleinii* | 0.553 | 0.711 | 0.297 |
| *Solea variegata* | - | 0.089 | - |
| *Solea vulgaris* | - | - | 0.253 |
| *Solea lutea* | - | 0.178 | - |
| *Pegusa lascaris* | 0.369 | - | - |
| *Monochirus hispidus* | - | 0.067 | - |
| Total: | 17.120 | 21.511 | 16.291 |
| Number of species: | 13 | 12 | 19 |

**A4**

| Station: | **A4** | **A4** |
|---|---|---|
| Date: | 12.01.88. | 18.10.88. |
| Depth (m): | 32 | 31-31.5 |
| Species list: | kg $h^{-1}$ | kg $15min.^{-1}$ |
| *Maia squinado* | 0.600 | - |
| *Pecten jacobaeus* | 0.300 | - |
| *Loligo vulgaris* | 2.280 | - |
| *Sepia officinalis* | 0.480 | 0.200 |
| *Sepia elegans* | 0.120 | 0.040 |
| *Eledone moschata* | 1.080 | 10.500 |
| *Scyliorhinus stellaris* | 0.240 | - |
| *Squalus acanthias* | 4.200 | 0.200 |
| *Raja clavata* | 12.600 | - |
| *Merluccius merluccius* | 0.240 | 1.100 |
| *Merlangius merlangus* | - | 0.400 |
| *Trisopterus minutus capelanus* | 10.800 | 0.600 |
| *Zeus faber* | - | 0.700 |
| *Serranus hepatus* | - | 1.000 |
| *Cepola rubescens* | - | 0.300 |
| *Trachurus mediterraneus* | 0.240 | 0.300 |
| *Pagellus erythrinus* | 0.540 | - |
| *Gobius niger* | 0.480 | - |
| *Callionymus maculatus* | - | 0.060 |
| *Scorpaena notata* | 0.120 | - |

*Table 2. cont'd*

| | | |
|---|---|---|
| *Scorpaena scrofa* | 1.680 | - |
| Total: | 36.000 | 15.400 |
| Number of species: | 16 | 12 |

**A6**

| Station: | **A6** | **A6** | **A6** |
|---|---|---|---|
| Date: | 12.01.88. | 18.10.88. | 08.01.91. |
| Depth (m): | 24 | 24-25 | 24 |
| Sp ecies list: | kg $h^{-1}$ | kg $h^{-1}$ | kg $h^{-1}$ |
| *Penaeus kerathurus* | - | - | 0.019 |
| *Squilla mantis* | - | - | 0.338 |
| *Pecten jacobaeus* | 0.039 | - | - |
| *Loligo vulgaris* | 0.349 | 2.478 | 0.844 |
| *Sepia officinalis* | 0.099 | 0.209 | 0.083 |
| *Sepia elegans* | 0.009 | - | - |
| *Sepiola sp.* | - | - | 0.431 |
| *Eledone moschata* | 6.499 | 22.435 | 8.063 |
| *Trygon pastinaca* | - | 0.417 | - |
| *Mustelus mustelus* | - | 17.217 | - |
| *Myliobatis aquila* | - | 0.313 | - |
| *Raja miraletus* | 0.075 | - | - |
| *Raja clavata* | 0.007 | - | - |
| *Raja asterias* | - | - | 0.563 |
| *Sardina pilchardus* | 0.030 | 1.304 | - |
| *Engraulis encrasicholus* | 0.009 | - | - |
| *Conger conger* | - | - | 0.938 |
| *Merlangius merlangus* | 0.399 | - | 0.019 |
| *Trisopterus minutus capelanus* | - | 0.600 | 6.750 |
| *Zeus faber* | 0.004 | 0.339 | - |
| *Trachurus mediterraneus* | 0.300 | 8.609 | 0.094 |
| *Mullus barbatus* | - | 4.278 | - |
| *Mullus surmuletus* | - | 0.052 | - |
| *Pagellus erythrinus* | - | 0.037 | - |
| *Gobius niger* | - | - | 0.300 |
| *Gobius minutus* | 0.024 | - | - |
| *Gobius quadrimaculatus* | 0.039 | - | 0.150 |
| *Boops boops* | - | 0.157 | - |
| *Blennius ocellaris* | - | - | 0.011 |
| *Callionymus maculatus* | - | - | 0.450 |
| *Spicara smaris* | - | 0.887 | - |
| *Trigla lucerna* | - | 0.209 | - |
| *Trigla gurnardus* | - | - | 0.023 |
| *Platichthys flesus* | 0.199 | - | - |
| *Solea vulgaris* | 0.099 | - | 0.356 |
| *Solea kleinii* | 0.300 | 0.261 | 1.406 |
| *Pegusa lascaris* | 0.300 | - | - |
| *Solea lutea* | - | 0.063 | 0.075 |
| *Monochirus hispidus* | - | - | 0.038 |
| Total: | 8.510 | 59.865 | 20.951 |
| Number of species: | 18 | 18 | 20 |

*Table 2. cont'd*

| | A7 | | |
|---|---|---|---|
| Station: | A7 | A7 | A7 |
| Date: | 12.01.88. | 18.10.88. | 08.01.91. |
| Depth (m): | 35 | 36-34 | 38 |
| Spe cies list: | kg $h^{-1}$ | kg $h^{-1}$ | kg $h^{-1}$ |
| *Nephrops norvegicus* | - | 0.113 | - |
| *Maia squinado* | 0.472 | - | - |
| *Loligo vulgaris* | 0.181 | 0.150 | 0.233 |
| *Sepia officinalis* | 1.745 | 1.850 | 1.667 |
| *Sepia orbignyana* | 0.021 | - | - |
| *Sepia elegans* | 1.163 | 0.133 | 0.167 |
| *Eledone moschata* | 1.345 | 14.500 | 1.933 |
| *Illex coindetti* | - | 0.083 | - |
| *Scyliorhinus canicula* | - | 0.133 | 0.167 |
| *Squalus acanthias* | - | 0.267 | 1.500 |
| *Mustelus mustelus* | - | 0.217 | 28.000 |
| *Raja clavata* | 1.127 | 0.283 | - |
| *Sardina pilchardus* | - | 0.003 | 0.160 |
| *Engraulis encrasicholus* | - | 0.003 | 0.067 |
| *Alosa fallax* | - | - | 0.050 |
| *Merluccius merluccius* | 1.527 | 6.833 | 6.833 |
| *Merlangius merlangus* | 0.090 | 0.050 | 0.600 |
| *Trisopterus minutus capelanus* | 0.120 | 0.217 | 14.500 |
| *Zeus faber* | 0.005 | - | - |
| *Serranus hepatus* | - | 0.020 | 0.267 |
| *Cepola rubescens* | 0.218 | 0.183 | 0.133 |
| *Trachurus mediterraneus* | 0.163 | 3.833 | 0.023 |
| *Mullus barbatus* | 0.145 | - | 0.200 |
| *Mullus surmuletus* | - | 0.067 | - |
| *Pagellus erythrinus* | - | 0.063 | 0.033 |
| *Scomber scomber* | - | 0.367 | 0.050 |
| *Spicara smaris* | 0.014 | 0.018 | - |
| *Phrynorhombus regius* | - | - | 0.017 |
| *Trigla lucerna* | - | 0.867 | - |
| *Trigla gurnardus* | - | 0.020 | - |
| *Arnoglossus laterna* | - | 0.003 | - |
| *Arnoglossus kessleri* | - | - | 0.033 |
| *Gobius niger* | 0.363 | 0.053 | - |
| *Gobius quadrimaculatus* | 0.109 | - | 0.667 |
| *Callionymus maculatus* | - | - | 0.767 |
| *Scorpaena notata* | - | - | 0.003 |
| *Blennius ocellaris* | 0.010 | 0.027 | - |
| *Boops boops* | - | 0.027 | - |
| *Solea vulgaris* | - | - | 0.100 |
| *Solea variegata* | - | - | 0.013 |
| *Solea lutea* | - | 0.007 | - |
| Total: | 8.818 | 30.390 | 58.183 |
| Number of species: | 18 | 29 | 26 |

*Table 2. cont'd*

| | B1 | | |
|---|---|---|---|
| Station: | **B1** | **B1** | **B1** |
| Date: | 13.01.88. | 19.10.88. | 10.01.91. |
| Depth (m): | 28 | 25 | 25 |
| Species list: | kg $h^{-1}$ | kg $h^{-1}$ | kg $h^{-1}$ |
| *Squilla mantis* | 3.499 | 9.081 | 4.833 |
| *Penaeus kerathurus* | - | 1.427 | 0.027 |
| *Loligo vulgaris* | - | 0.697 | - |
| *Alotheutis media* | 0.036 | 0.195 | 0.300 |
| *Sepia officinalis* | - | 7.946 | 0.005 |
| *Sepiolidae* | 0.006 | - | 0.033 |
| *Sardina pilchardus* | 0.053 | 2.920 | - |
| *Sprattus sprattus* | 0.009 | 0.357 | 0.012 |
| *Engraulis encrasicolus* | - | 1.622 | - |
| *Alosa fallax* | - | 0.210 | - |
| *Conger conger* | - | 0.973 | 0.427 |
| *Merluccius merluccius* | 0.066 | 0.308 | 1.367 |
| *Serranus hepatus* | - | 0.013 | - |
| *Zeus faber* | - | - | 0.001 |
| *Atherina boyeri* | 0.199 | - | 1.167 |
| *Trisopterus minutus capelanus* | - | 0.827 | - |
| *Cepola rubescens* | - | 0.357 | - |
| *Trachurus mediterraneus* | - | 0.308 | - |
| *Mullus barbatus* | - | 54.324 | - |
| *Diplodus annularis* | - | 0.045 | 0.007 |
| *Pagellus erythrinus* | - | 0.026 | - |
| *Umbrina cirrosa* | 0.066 | 0.810 | 0.417 |
| *Lithognathus mormyrus* | 0.049 | - | - |
| *Scomber scomber* | 0.083 | 0.130 | - |
| *Mugil capito* | - | 3.568 | 0.067 |
| *Mugil auratus* | 0.900 | - | 0.057 |
| *Gobius niger* | 0.233 | 0.324 | 0.733 |
| *Gobius ophiocephalus* | - | - | 0.017 |
| *Dicentrarchus labrax* | - | - | 0.067 |
| *Boops boops* | - | 0.146 | - |
| *Blennius ocellaris* | - | 0.052 | - |
| *Trigla lucerna* | 0.133 | 0.178 | 0.047 |
| *Arnoglossus kessleri* | - | - | 0.027 |
| *Scophthalmus rhombus* | 0.083 | - | - |
| *Platichthys flesus* | 0.039 | - | 0.267 |
| *Solea vulgaris* | 0.566 | 0.195 | 0.300 |
| *Solea lascaris* | 0.030 | - | 0.040 |
| *Solea lutea* | 0.183 | 0.055 | - |
| *Microchirus variegatus* | - | - | - |
| *Gaidropsarus megalokynodon* | - | - | 0.077 |
| Total: | 6.233 | 87.094 | 10.295 |
| Number of species: | 18 | 27 | 23 |

*Table 2. cont'd*

**B2**

| Station: | B2 | B2 | B2 |
|---|---|---|---|
| Date: | 13.01.88. | 19.10.88. | 09.01.91. |
| Depth (m): | 37 | 36-38 | 37 |
| Species list: | kg $h^{-1}$ | kg $h^{-1}$ | kg $h^{-1}$ |
| *Squilla mantis* | 0.079 | 0.667 | 0.010 |
| *Nephrops norvegicus* | - | 0.467 | - |
| *Penaeus kerathurus* | - | - | 0.033 |
| *Loligo vulgaris* | 0.216 | - | 0.367 |
| *Alloteuthis media* | 0.300 | - | - |
| *Sepia officinalis* | 0.516 | 0.040 | 2.167 |
| *Sepia orbignyana* | 0.023 | - | - |
| *Sepia elegans* | 0.499 | - | 0.087 |
| *Sepiolidae* | 0.001 | - | - |
| *Eledone moschata* | 0.006 | 1.733 | - |
| *Mustelus mustelus* | 0.566 | - | - |
| *Squalus acanthias* | 15.666 | - | - |
| *Raja clavata* | 1.533 | - | - |
| *Sardina pilchardus* | 0.066 | - | - |
| *Sprattus sprattus* | - | - | 0.093 |
| *Engraulis enchrasicholus* | 0.099 | - | - |
| *Conger conger* | 0.033 | 1.733 | - |
| *Merluccius merluccius* | 4.999 | 0.333 | 3.667 |
| *Merlangius merlangus* | - | - | 0.150 |
| *Trisopterus minutus capelanus* | 1.133 | - | 10.167 |
| *Zeus faber* | 0.009 | - | - |
| *Serranus hepatus* | 0.199 | - | 0.117 |
| *Cepola rubescens* | 1.733 | - | - |
| *Trachurus mediterraneus* | 0.600 | - | 0.050 |
| *Mullus barbatus* | 0.026 | 0.027 | 0.013 |
| *Diplodus annularis* | 0.013 | - | 0.083 |
| *Pagellus erythrinus* | 0.033 | - | - |
| *Scomber scomber* | 0.016 | - | - |
| *Mugil capito* | - | 0.100 | - |
| *Gobius niger* | 0.183 | - | 0.183 |
| *Callionymus sp.* | 0.023 | - | - |
| *Blennius ocellaris* | 0.079 | - | - |
| *Trigla lucerna* | 0.066 | - | - |
| *Phrynorhombus regius* | 0.023 | - | - |
| *Arnoglossus laterna* | 0.233 | - | - |
| *Arnoglossus kessleri* | - | - | 0.033 |
| *Solea lutea* | 0.009 | - | - |
| *Solea vulgaris* | - | - | 0.083 |
| Total: | 28.980 | 5.100 | 17.303 |
| Number of species: | 31 | 8 | 16 |

**B3**

| Station: | B3 | B3 | B3 |
|---|---|---|---|
| Date: | 11.01.88. | 17.10.88. | 08.01.91. |
| Depth (m): | 37 | 37-36 | 39 |
| Species list: | kg $h^{-1}$ | kg $h^{-1}$ | kg $h^{-1}$ |
| *Nephrops norvegicus* | 0.188 | 1.333 | - |
| *Pecten jacobaeus* | 0.034 | - | - |
| *Loligo vulgaris* | 0.092 | 0.050 | 0.646 |
| *Aloteuthis media* | - | - | 0.431 |
| *Sepia officinalis* | 0.994 | 0.800 | 3.385 |
| *Sepia elegans* | 0.168 | 0.160 | 0.769 |

*Table 2. cont'd*

| | | | |
|---|---|---|---|
| *Eledone moschata* | - | 0.267 | 0.138 |
| *Illex coindetii* | - | 0.033 | - |
| *Mustelus mustelus* | 0.171 | - | - |
| *Torpedo marmorata* | 0.342 | - | - |
| *Sardina pilchardus* | - | - | 0.166 |
| *Engraulis encrasicolus* | - | - | 0.062 |
| *Conger conger* | - | 0.083 | - |
| *Merluccius merluccius* | 1.337 | 1.900 | 0.600 |
| *Merlangius merlangus* | - | - | 6.000 |
| *Trisopterus minutus capelanus* | 0.075 | 0.117 | 0.800 |
| *Zeus faber* | - | 0.050 | - |
| *Serranus hepatus* | - | 0.033 | 1.077 |
| *Cepola rubescens* | - | 0.117 | - |
| *Trachurus mediterraneus* | 0.051 | - | 0.369 |
| *Mullus barbatus* | 0.205 | - | 0.200 |
| *Diplodus annularis* | - | - | 0.037 |
| *Scomber scomber* | 0.120 | 0.050 | - |
| *Gobius niger* | 0.188 | 0.030 | 0.862 |
| *Gobius quadrimaculatus* | - | - | 0.006 |
| *Callionymus maculatus* | - | - | 0.018 |
| *Trigla lucerna* | 0.205 | 0.123 | - |
| *Trigla gurnardus* | - | 0.013 | - |
| *Phrynorhombus regius* | - | - | 0.008 |
| *Arnoglossus kessleri* | - | - | 0.068 |
| *Solea lutea* | - | - | 0.015 |
| *Gaidropsarus megalokynodon* | - | 0.030 | - |
| Total: | 4.170 | 5.189 | 15.657 |
| Number of species: | 14 | 17 | 20 |

**B4**

| Station: | **B4** | **B4** | **B4** |
|---|---|---|---|
| Date: | 11.01.88. | 17.10.88. | 08.01.91. |
| Depth (m): | 42 | 41-39.5 | 43 |
| Species list: | kg $h^{-1}$ | kg $h^{-1}$ | kg $h^{-1}$ |
| *Squilla mantis* | - | 0.010 | - |
| *Nephrops norvegicus* | 0.018 | 0.617 | - |
| *Maia squinado* | - | 0.400 | - |
| *Pecten jacobaeus* | 0.032 | - | - |
| *Loligo vulgaris* | 0.254 | 0.950 | 1.367 |
| *Alloteuthis media* | 0.032 | - | 0.033 |
| *Sepia officinalis* | 1.345 | 0.200 | 2.433 |
| *Sepia elegans* | 1.163 | 0.900 | 0.050 |
| *Sepiolidae* | 0.006 | - | - |
| *Eledone moschata* | 2.400 | 9.167 | 0.167 |
| *Illex coindetii* | - | 0.133 | - |
| *Squalus acanthias* | - | 0.133 | - |
| *Mustelus mustelus* | 1.672 | - | - |
| *Mustelus asterias* | - | - | 1.133 |
| *Scyliorhinus canicula* | - | 0.217 | 1.200 |
| *Raja clavata* | - | - | 0.617 |
| *Sardina aurita* | - | - | 0.167 |
| *Sardina pilchardus* | 0.290 | 1.067 | 0.500 |

*Table 3. cont'd*

| | | | |
|---|---|---|---|
| *Sprattus sprattus* | - | - | 0.067 |
| *Lophius budegassa* | - | - | 0.367 |
| *Conger conger* | 0.025 | - | - |
| *Merluccius merluccius* | 1.345 | 2.267 | 1.767 |
| *Merlangius merlangus* | - | 0.133 | 0.040 |
| *Trisopterus minutus capelanus* | 1.054 | 0.167 | 4.933 |
| *Gaidropsarus mediterraneus* | 0.007 | - | - |
| *Serranus hepatus* | 0.047 | 0.060 | 0.134 |
| *Cepola rubescens* | 0.872 | 0.433 | 0.100 |
| *Trachurus mediterraneus* | 0.381 | 0.800 | 0.317 |
| *Mullus barbatus* | 0.120 | 0.027 | 0.250 |
| *Mullus surmuletus* | - | 0.123 | - |
| *Pagellus erythrius* | 0.083 | 0.030 | 0.033 |
| *Pagellus acarne* | - | 0.033 | - |
| *Spicara smaris* | 0.010 | - | - |
| *Scomber scomber* | 0.109 | - | 0.033 |
| *Gobius niger* | 0.079 | 0.067 | - |
| *Gobius quadrimaculatus* | - | 0.005 | - |
| *Gobius minutus* | 0.552 | - | - |
| *Callionymus maculatus* | 0.002 | 0.005 | - |
| *Blennius ocellaris* | 0.014 | 0.043 | - |
| *Trigla lastoviza* | - | - | 0.017 |
| *Trigla lucerna* | - | 0.467 | 0.167 |
| *Trigla gurnardus* | - | 0.040 | - |
| *Trigla lineata* | - | 0.033 | - |
| *Arnoglossus thori* | - | 0.013 | - |
| *Phrynorhombus regius* | - | 0.003 | - |
| *Scorpaena notata* | 0.012 | 0.150 | 0.050 |
| *Arnoglossus laterna* | 0.036 | 0.007 | - |
| *Monochirus hispidus* | - | - | 0.010 |
| *Solea lutea* | 0.012 | - | - |
| *Solea variegata* | 0.010 | 0.033 | 0.013 |
| *Citharus linguatula* | - | - | 0.023 |
| *Gaidropsarus megalokynodon* | - | 0.013 | - |
| Total: | 11.939 | 18.746 | 15.988 |
| Number of species: | 29 | 34 | 27 |

*Table 3. Quantitative and qualitative (No;kg) list of the species collected during PIPETA trawl survey expedition in 1988 (January, October) and 1991 (January)*

| | A2 | | | | | |
|---|---|---|---|---|---|---|
| Station: | A2 | | A2 | | A2 | |
| Date: | 12.01.88. | | 19.10.88. | | 09.01.91. | |
| Depth (m): | 25 | | 24-26 | | 28 | |
| Species list: | No | kg $h^{-1}$ | No | kg $h^{-1}$ | No | kg $h^{-1}$ |
| *Suberites domuncula* | 46 | 1.010 | 58 | 1.160 | 105 | 2.400 |
| *Calliactis parasitica* | 369 | 1.220 | 416 | 1.405 | - | - |
| *Aphrodita aculeata* | 5 | 0.150 | - | - | 15 | 0.150 |
| *Squilla mantis* | - | - | 3 | 0.190 | - | - |
| *Sicyonia carinata* | 8 | 0.005 | - | - | 40 | 0.020 |
| *Penaeus kerathurus* | - | - | 2 | 0.040 | - | - |

*Table 3. cont'd*

| | | | | | | |
|---|---|---|---|---|---|---|
| *Paguristes oculatus* | 877 | 1.755 | 1223 | 1.345 | 541 | 0.925 |
| *Pagurus prideaux* | 14 | 0.070 | 13 | 0.065 | - | - |
| *Ethusa mascarone* | - | - | - | - | 75 | 0.075 |
| *Macropodia rostrata* | 20 | 0.025 | - | - | 68 | 0.060 |
| *Inachus dorsettensis* | 52 | 0.075 | 45 | 0.065 | 494 | 0.750 |
| *Corystes cassivelaunus* | 37 | 0.280 | - | - | 885 | 2.850 |
| *Liocarcinus depurator* | 9 | 0.160 | 13 | 0.260 | 8 | 0.120 |
| *Gibbula magus* | 5 | 0.020 | 13 | 0.035 | 23 | 0.115 |
| *Aporrhais pespelecani* | - | - | 19 | 0.095 | - | - |
| *Diodora graeca* | - | - | 6 | 0.020 | 8 | 0.020 |
| *Naticarius stercusmuscarum* | 9 | 0.135 | 14 | 0.035 | 8 | 0.200 |
| *Trunculariopsis trunculus* | - | - | 6 | 0.240 | - | - |
| *Fusinus rostratus* | 9 | 0.030 | 19 | 0.065 | - | - |
| *Philine aperta* | - | - | 18 | 0.030 | 24 | 0.040 |
| *Pinna pectinata* | 3 | 1.000 | - | - | - | - |
| *Chlamys opercularis* | 162 | 1.620 | 1088 | 12.165 | 135 | 0.900 |
| *Chlamys varius* | 10 | 0.075 | 13 | 0.100 | 45 | 0.225 |
| *Protopecten glaber* | - | - | - | - | 68 | 0.680 |
| *Pecten jacobaeus* | - | - | 1 | 0.100 | - | - |
| *Ostrea edulis* | - | - | - | - | 8 | 0.880 |
| *Laevicardium oblongum* | 14 | 0.280 | 13 | 0.160 | 8 | 0.040 |
| *Cardium aculeatum* | 5 | 0.750 | 6 | 0.600 | - | - |
| *Cucumaria planci* | 291 | 6.600 | 109 | 1.410 | 30 | 0.600 |
| *Echinus acutus* | 1 | 0.160 | - | - | 1 | 0.320 |
| *Psammechinus microtuberculatus* | 198 | 0.690 | 85 | 0.130 | 840 | 1.885 |
| *Astropecten irregularis* | 5 | 0.025 | - | - | - | - |
| *Ophiura texturata* | 138 | 0.185 | 192 | 0.255 | 390 | 0.635 |
| *Ophiothrix quinquemaculata* | 285 | 0.185 | 400 | 0.260 | 714 | 0.600 |
| *Phallusia mammilata* | 14 | 1.020 | 19 | 3.480 | - | - |
| *Styela sp.* | - | - | - | - | 1110 | 2.255 |
| *Microcosmus sulcatus* | 14 | 0.795 | 6 | 0.180 | 15 | 0.450 |
| Total: | 2600 | 18.420 | 3800 | 23.890 | 6011 | 18.070 |
| Number of species: | 26 | | 26 | | 27 | |

**A3**

| Station: | **A3** | | **A3** | | **A3** | |
|---|---|---|---|---|---|---|
| Date: | 12.01.88. | | 18.10.88. | | 09.01.91. | |
| Depth (m): | 25 | | 24-25 | | 26 | |
| Species list: | No | kg $h^{-1}$ | No | kg $h^{-1}$ | No | kg $h^{-1}$ |
| *Suberites domuncula* | 180 | 3.120 | 490 | 7.000 | 130 | 0.235 |
| *Calliactis parasitica* | 390 | 1.290 | 764 | 2.660 | 432 | 1.440 |
| *Hermonia hystrix* | - | - | - | - | 12 | 0.030 |
| *Sicyonia carinata* | - | - | - | - | 288 | 0.150 |
| *Processa canaliculata* | - | - | - | - | 406 | 0.195 |
| *Paguristes oculatus* | 1716 | 3.040 | 4882 | 7.715 | 1649 | 2.945 |
| *Ethusa mascarone* | 17 | 0.020 | 27 | 0.015 | 40 | 0.060 |
| *Macropodia rostrata* | 36 | 0.030 | - | - | 377 | 0.260 |
| *Inachus dorsettensis* | 54 | 0.090 | 82 | 0.135 | 250 | 0.330 |
| *Corystes cassivelaunus* | 48 | 0.270 | - | - | 131 | 0.590 |
| *Liocarcinus depurator* | 6 | 0.090 | 27 | 0.540 | 144 | 0.785 |
| *Pilumnus hirtellus* | 36 | 0.120 | - | - | - | - |
| *Diodora graeca* | 12 | 0.030 | 27 | 0.110 | 27 | 0.035 |

*Table 3. cont'd*

| | | | | | | |
|---|---|---|---|---|---|---|
| *Gibbula magus* | 18 | 0.060 | 123 | 0.410 | 105 | 0.480 |
| *Calliostoma zizyphinus* | 6 | 0.030 | - | - | - | - |
| *Aporrhais pespelecani* | - | - | 41 | 0.135 | - | - |
| *Naticarius stercusmuscarum* | 18 | 0.210 | 41 | 0.275 | - | - |
| *Truncullariopsis trunculus* | 18 | 1.140 | - | - | 26 | 0.780 |
| *Murex brandaris* | 6 | 0.150 | 82 | 1.640 | 26 | 0.325 |
| *Fusinus rostratus* | 5 | 0.015 | - | - | - | - |
| *Philine aperta* | 96 | 0.060 | - | - | 104 | 0.065 |
| *Scaphander lignarius* | - | - | 14 | 0.030 | - | - |
| *Chlamys opercularis* | 30 | 0.150 | 205 | 2.460 | 96 | 1.440 |
| *Chlamys varius* | 24 | 0.150 | 82 | 0.685 | 13 | 0.195 |
| *Pecten jacobaeus* | - | - | 8 | 0.535 | - | - |
| *Protopecten glaber* | - | - | - | - | 144 | 1.965 |
| *Laevicardium oblongum* | 174 | 5.100 | 41 | 0.685 | 26 | 0.390 |
| *Mantellum hians* | - | - | - | - | 26 | 0.020 |
| *Cardium aculeatum* | 1 | 0.060 | 14 | 0.840 | - | - |
| *Pitaria chione* | 1 | 0.100 | 3 | 0.300 | - | - |
| *Holothuria tubulosa* | - | - | 41 | 9.550 | - | - |
| *Cucumaria planci* | 48 | 1.080 | 205 | 4.100 | 118 | 1.575 |
| *Phyllophorus urna* | - | - | - | - | 3 | 0.015 |
| *Sphaerechinus granularis* | - | - | 41 | 0.135 | 26 | 0.675 |
| *Echinus acutus* | - | - | - | - | 2 | 0.300 |
| *Psammechinus microtuberculatus* | 270 | 0.720 | 615 | 1.770 | 2225 | 3.540 |
| *Ophiothrix quinquemaculata* | 2250 | 2.700 | 545 | 0.410 | 1060 | 1.570 |
| *Ophiura texturata* | 840 | 0.780 | 341 | 0.410 | 104 | 0.260 |
| *Phallusia mammilata* | 6 | 0.480 | 41 | 3.690 | 65 | 3.250 |
| *Microcosmus sulcatus* | 48 | 2.100 | 136 | 3.265 | 13 | 0.650 |
| *Botryllus schlosseri* | - | - | - | - | 39 | 0.910 |
| Total: | 6354 | 23.185 | 8998 | 89.500 | 8107 | 25.460 |
| Number of species: | 28 | | 26 | | 31 | |

A4

| Station: | A4 | | A4 | |
|---|---|---|---|---|
| Date: | 12.01.88. | | 18.10.88. | |
| **Depth (m):** | **32** | | **31-31.5** | |
| Species list: | No | kg $h^{-1}$ | No | kg 15min.$^{-1}$ |
| *Suberites carnosus* | 90 | 4.080 | 20 | 0.600 |
| *Cliona celata* | - | - | 2 | 1.150 |
| *Calliactis parasitica* | 30 | 0.060 | 25 | 0.050 |
| *Virgularia mirabilis* | 96 | 0.240 | - | - |
| *Aphrodita aculeata* | 144 | 1.800 | 25 | 0.200 |
| *Paguristes oculatus* | 162 | 0.210 | 45 | 0.075 |
| *Pagurus sp.* | - | - | 50 | 0.025 |
| *Inachus dorsettensis* | 180 | 0.300 | 125 | 0.100 |
| *Maia squinado* | 1 | 0.600 | - | - |
| *Liocarcinus depurator* | - | - | 5 | 0.150 |
| *Pilumnus hirtellus* | 4 | 0.035 | - | - |
| *Truncullariopsis trunculus* | - | - | 3 | 0.240 |
| *Fusinus rostratus* | - | - | 115 | 0.225 |
| *Philine aperta* | 24 | 0.090 | 75 | 0.225 |
| *Pinna pectinata* | 14 | 3.950 | 18 | 5.100 |
| *Chlamys opercularis* | 364 | 5.810 | 3785 | 32.500 |

*Table 3. cont'd*

| | | | | |
|---|---|---|---|---|
| *Pecten jacobaeus* | 1 | 0.300 | - | - |
| *Cardium paucicostatum* | - | - | 10 | 0.025 |
| *Aloidis gibba* | 492 | 0.240 | - | - |
| *Holothuria tubulosa* | - | - | 5 | 0.450 |
| *Cucumaria planci* | 378 | 7.560 | 425 | 7.750 |
| *Echinus acutus* | 6 | 0.840 | 1 | 0.300 |
| *Psammechinus microtuberculatus* | 300 | 1.440 | 205 | 1.000 |
| *Astropecten irregularis* | 78 | 0.840 | 110 | 0.750 |
| *Ophiothrix quinquemaculata* | 540 | 0.780 | 100 | 0.175 |
| *Ophiura texturata* | 330 | 0.300 | 225 | 0.250 |
| *Microcosmus sulcatus* | 6 | 3.300 | - | - |
| *Styela sp.* | - | - | 90 | 0.350 |
| Total: | 3240 | 29.775 | 5464 | 71.690 |
| Number of species: | 20 | | 22 | |

**A6**

| Station: | A6 | | A6 | | A6 | |
|---|---|---|---|---|---|---|
| Date: | 12.01.88. | | 18.10.88. | | 08.01.91. | |
| Depth (m): | 24 | | 24-25 | | 24 | |
| Species list: | No | kg $h^{-1}$ | No | kg $h^{-1}$ | No | kg $h^{-1}$ |
| *Suberites domuncula* | 525 | 11.550 | 2160 | 31.190 | 309 | 3.950 |
| *Tethya aurantium* | - | - | 4 | 0.300 | - | - |
| *Calliactis parasitica* | 825 | 2.700 | 792 | 3.360 | 343 | 1.200 |
| *Hermonia hystrix* | - | - | - | - | 34 | 0.085 |
| *Sicyonia carinata* | 90 | 0.035 | - | - | 291 | 0.190 |
| *Squilla mantis* | - | - | - | - | 5 | 0.340 |
| *Penaeus kerathurus* | - | - | - | - | 1 | 0.020 |
| *Processa canaliculata* | - | - | - | - | 257 | 0.120 |
| *Paguristes oculatus* | 2850 | 4.415 | 6240 | 9.610 | 1389 | 2.565 |
| *Pagurus prideaux* | 120 | 0.750 | 192 | 1.200 | - | - |
| *Ethusa mascarone* | - | - | 48 | 0.050 | - | - |
| *Macropodia rostrata* | 225 | 0.225 | 240 | 0.240 | 430 | 0.515 |
| *Inachus dorsettensis* | - | - | 360 | 0.600 | 102 | 0.170 |
| *Parthenope angulifrons* | - | - | - | - | 17 | 0.050 |
| *Corystes cassivelaunus* | 120 | 0.300 | - | - | 480 | 1.285 |
| *Liocarcinus depurator* | - | - | - | - | 171 | 1.370 |
| *Pilumnus hirtellus* | 45 | 0.150 | - | - | 17 | 0.050 |
| *Diodora graeca* | 30 | 0.075 | 72 | 0.240 | - | - |
| *Gibbula magus* | 105 | 0.300 | 840 | 2.400 | 223 | 0.670 |
| *Astraea rugosa* | 30 | 0.225 | 5 | 0.050 | - | - |
| *Galeodea echinophora* | - | - | - | - | 17 | 0.510 |
| *Trunculariopsis trunculus* | - | - | 48 | 3.120 | 17 | 0.595 |
| *Murex brandaris* | 30 | 0.750 | 96 | 2.400 | 17 | 0.255 |
| *Philine aperta* | 240 | 0.150 | - | - | - | - |
| *Pinna pectinata* | - | - | 3 | 1.100 | - | - |
| *Chlamys opercularis* | 150 | 0.900 | 432 | 5.280 | 86 | 1.550 |
| *Chlamys varius* | 150 | 0.900 | 408 | 3.600 | 70 | 0.175 |
| *Protopecten glaber* | - | - | - | - | 137 | 2.570 |
| *Pecten jacobaeus* | 1 | 0.040 | 1 | 0.140 | - | - |
| *Mantellum hians* | - | - | - | - | 35 | 0.035 |
| *Musculus subpictus* | - | - | - | - | 5383 | 1.290 |
| *Laevicardium oblongum* | 30 | 0.150 | - | - | - | - |
| *Cardium paucicostatum* | - | - | 48 | 0.120 | - | - |
| *Holothuria tubulosa* | - | - | 96 | 19.200 | 17 | 2.040 |
| *Cucumaria planci* | 30 | 0.600 | 216 | 3.600 | - | - |
| *Echinus acutus* | - | - | - | - | 1 | 0.100 |
| *Sphaerechinus granularis* | - | - | 72 | 6.000 | - | - |
| *Psammechinus microtuberculatus* | 2760 | 4.195 | 4800 | 12.000 | 1114 | 2.060 |

*Table 3. cont'd*

| | | | | | | |
|---|---|---|---|---|---|---|
| *Astropecten irregularis* | - | - | 24 | 0.120 | - | - |
| *Ophiothrix quinquemaculata* | 4440 | 5.330 | 3600 | 3.130 | 2297 | 3.765 |
| *Ophiura texturata* | 975 | 1.500 | 1560 | 1.795 | 188 | 0.255 |
| *Distoma adriaticum* | 30 | 0.300 | 24 | 0.240 | - | - |
| *Phallusia mammilata* | 30 | 2.100 | 10 | 0.800 | 69 | 6.040 |
| *Microcosmus sulcatus* | 450 | 12.000 | 384 | 10.800 | - | - |
| Total: | 14281 | 49.640 | 22775 | 122.685 | 13517 | 33.820 |
| Number of species: | 24 | | 28 | | 29 | |

**A7**

| Station: | A7 | | A7 | | A7 | |
|---|---|---|---|---|---|---|
| Date: | 12.01.88. | | 18.10.88. | | 08.01.91. | |
| Depth (m): | 35 | | 36-34 | | 38 | |
| Species list: | No | kg $h^{-1}$ | No | kg $h^{-1}$ | No | kg $h^{-1}$ |
| *Suberites domuncula* | 7 | 0.490 | 21 | 1.680 | - | - |
| *Suberites carnosus* | 16 | 0.560 | 107 | 4.280 | 280 | 4.465 |
| *Cliona celata* | 11 | 1.650 | 8 | 5.050 | - | - |
| *Calliactis parasitica* | - | - | 43 | 0.160 | - | - |
| *Virgularia mirabilis* | 24 | 0.060 | - | - | - | - |
| *Aphrodita aculeata* | 86 | 1.310 | 85 | 1.380 | - | - |
| *Nephrops norvegicus* | - | - | 2 | 0.115 | - | - |
| *Paguristes oculatus* | 428 | 0.430 | 32 | 0.055 | - | - |
| *Pagurus sp.* | - | - | 427 | 0.375 | 12 | 0.010 |
| *Ethusa mascarone* | - | - | - | - | 67 | 0.050 |
| *Macropodia rostrata* | 14 | 0.010 | - | - | - | - |
| *Inachus dorsettensis* | 34 | 0.035 | 107 | 0.055 | 13 | 0.050 |
| *Maia squinado* | 1 | 0.470 | - | - | - | - |
| *Liocarcinus depurator* | 11 | 0.175 | 11 | 0.330 | 67 | 0.940 |
| *Turritella communis* | - | - | - | - | 190 | 0.135 |
| *Fusinus rostratus* | 72 | 0.190 | 352 | 0.850 | - | - |
| *Philine aperta* | 8 | 0.025 | 160 | 0.270 | 960 | 2.130 |
| *Pinna pectinata* | 2 | 0.400 | 23 | 8.000 | 10 | 2.500 |
| *Chlamys opercularis* | 60 | 0.135 | 5781 | 36.245 | 373 | 2.000 |
| *Mytilus galloprovincialis* | 2 | 0.150 | 4 | 0.330 | - | - |
| *Pecten jacobaeus* | - | - | 1 | 0.150 | 1 | 0.025 |
| *Ostrea edulis* | 7 | 0.770 | 3 | 0.750 | - | - |
| *Isocardia cor* | - | - | 1 | 0.150 | - | - |
| *Laevicardium oblongum* | 2 | 0.070 | - | - | 253 | 1.065 |
| *Caridium paucicostatum* | - | - | - | - | 30 | 0.065 |
| *Pitaria rudis* | - | - | - | - | 68 | 0.085 |
| *Musculus subpictus* | - | - | - | - | 16400 | 3.935 |
| *Aloidis gibba* | 473 | 0.270 | 22400 | 11.200 | 4000 | 1.680 |
| *Holothuria tubulosa* | 5 | 0.450 | - | - | - | - |
| *Cucumaria planci* | 124 | 2.190 | 149 | 3.200 | - | - |
| *Echinus acutus* | 7 | 1.400 | 1 | 0.300 | - | - |
| *Psammechinus microtuberculatus* | 7 | 0.060 | 32 | 0.160 | 27 | 0.135 |
| *Astropecten irregularis* | 23 | 0.255 | 171 | 0.015 | 92 | 0.115 |
| *Ophiothrix quinquemaculata* | 17 | 0.015 | 107 | 0.055 | - | - |
| *Ophiura texturata* | 49 | 0.045 | 320 | 0.215 | 150 | 0.085 |
| *Distoma adriaticum* | 5 | 0.100 | - | - | - | - |
| *Phallusia mammilata* | 2 | 0.180 | 4 | 0.430 | - | - |
| *Styela sp.* | 113 | 0.270 | 13000 | 51.100 | - | - |
| *Microcosmus sulcatus* | 52 | 3.900 | 5 | 0.595 | - | - |

*Table 3. cont'd*

| | | | | | | |
|---|---|---|---|---|---|---|
| Total: | 1662 | 16.065 | 43357 | 128.495 | 22993 | 19.470 |
| Number of species: | 29 | | 28 | | | 18 |

**B1**

| Station: | B1 | | B1 | | B1 | |
|---|---|---|---|---|---|---|
| Date: | 13.01.88. | | 19.10.88. | | 10.01.91. | |
| Depth (m): | 28 | | 25 | | 25 | |
| Species list: | No | kg $h^{-1}$ | No | kg $h^{-1}$ | No | kg $h^{-1}$ |
| *Aiptasia sp.* | 420 | 0.340 | 600 | 0.480 | - | - |
| *Virgularia mirabilis* | - | - | - | - | 35 | 0.035 |
| *Sternaspis scutata* | - | - | 10 | 0.005 | 13 | 0.010 |
| *Squilla mantis* | 106 | 3.500 | 229 | 9.080 | 162 | 4.835 |
| *Sicyonia carinata* | 30 | 0.020 | - | - | 13 | 0.010 |
| *Penaeus kerathurus* | - | - | 68 | 1.425 | 2 | 0.025 |
| *Processa canaliculata* | 84 | 0.040 | - | - | 27 | 0.015 |
| *Macropodia rostrata* | 72 | 0.060 | - | - | 42 | 0.035 |
| *Inachus dorsettensis* | 20 | 0.020 | - | - | - | - |
| *Liocarcinus depurator* | 266 | 2.460 | 2 | 0.030 | 1707 | 14.000 |
| *Carcinides maenas* | 8 | 0.240 | - | - | - | - |
| *Turritella communis* | 32 | 0.050 | 44 | 0.070 | 13 | 0.025 |
| *Aporrhais pespelecani* | 26 | 0.130 | 48 | 0.210 | 27 | 0.135 |
| *Sphaeronassa mutabilis* | 562 | 1.515 | 384 | 1.100 | 194 | 0.535 |
| *Naticarius stercusmuscarum* | 12 | 0.130 | 10 | 0.090 | - | - |
| *Hinia reticulata* | 130 | 0.370 | 328 | 0.700 | 87 | 0.235 |
| *Philine aperta* | 178 | 0.310 | 8 | 0.010 | 20 | 0.025 |
| *Pinna pectinata* | - | - | 1 | 0.650 | - | - |
| *Arca corbuloides* | 16 | 0.200 | 12 | 0.140 | 13 | 0.260 |
| *Cardium paucicostatum* | 6 | 0.010 | 5 | 0.005 | 7 | 0.005 |
| *Pitaria rudis* | - | - | 10 | 0.010 | 20 | 0.025 |
| *Venerupis aurea* | 22 | 0.090 | - | - | - | - |
| *Aloidis gibba* | 228 | 0.080 | 200 | 0.090 | 166 | 0.070 |
| *Cucumaria planci* | - | - | 4 | 0.060 | - | - |
| *Schizaster canaliferus* | 2 | 0.030 | 4 | 0.060 | - | - |
| *Astropecten irregularis* | 36 | 0.100 | 112 | 0.400 | 180 | 1.200 |
| *Ophiura texturata* | 336 | 0.300 | 164 | 0.150 | 93 | 0.100 |
| Total: | 2592 | 9.995 | 2243 | 14.765 | 2821 | 21.580 |
| Number of species: | 21 | | 20 | | 19 | |

**B2**

| Station: | B2 | | B2 | | B2 | |
|---|---|---|---|---|---|---|
| Date: | 13.01.88. | | 19.10.88. | | 09.01.91. | |
| Depth (m): | 37 | | 36-38 | | 37 | |
| Species list: | No | kg $h^{-1}$ | No | kg $h^{-1}$ | No | kg $h^{-1}$ |
| *Suberites carnosus* | - | - | 10 | 1.670 | 8 | 0.320 |
| *Amphianthus dohrnii* | 28 | 0.015 | - | - | - | - |
| *Virgularia mirabilis* | 67 | 0.135 | 67 | 0.135 | 240 | 0.320 |
| *Aphrodita aculeata* | - | - | 3 | 0.120 | - | - |
| *Squilla mantis* | 2 | 0.080 | 14 | 0.665 | 1 | 0.010 |
| *Penaeus kerathurus* | - | - | - | - | 2 | 0.035 |
| *Pontocaris cataphracta* | - | - | - | - | 56 | 0.040 |
| *Processa canaliculata* | - | - | - | - | 60 | 0.030 |
| *Nephrops norvegicus* | - | - | 8 | 0.465 | - | - |
| *Pagurus sp.* | 81 | 0.095 | 17 | 0.010 | - | - |
| *Macropodia rostrata* | - | - | - | - | 44 | 0.040 |
| *Inachus dorsettensis* | - | - | - | - | 16 | 0.020 |

*Table 3. cont'd*

| | | | | | | |
|---|---|---|---|---|---|---|
| *Alpheus glaber* | - | - | 8 | 0.010 | - | - |
| *Liocarcinus depurator* | 133 | 2.340 | 113 | 1.660 | 8 | 0.060 |
| *Gonoplax angulata* | - | - | 4 | 0.015 | - | - |
| *Turritella communis* | 395 | 0.695 | 127 | 0.200 | 3100 | 4.870 |
| *Sphaeronassa mutabilis* | 10 | 0.025 | - | - | - | - |
| *Hinia reticulata* | 9 | 0.030 | - | - | - | - |
| *Philine aperta* | 149 | 0.345 | - | - | 1200 | 2.245 |
| *Fimbria fimbria* | 3 | 0.240 | - | - | - | - |
| *Pinna pectinata* | - | - | - | - | 1 | 0.020 |
| *Chlamys opercularis* | - | - | - | - | 128 | 0.880 |
| *Pecten jacobaeus* | - | - | 1 | 0.200 | - | - |
| *Ostrea edulis* | 13 | 0.780 | 23 | 0.990 | - | - |
| *Laevicardium oblongum* | - | - | - | - | 160 | 7.200 |
| *Cardium paucicostatum* | - | - | - | - | 304 | 1.120 |
| *Aloidis gibba* | - | - | - | - | 8080 | 1.615 |
| *Cucumaria planci* | 32 | 0.880 | 7 | 0.070 | - | - |
| *Astropecten irregularis* | 45 | 0.265 | 197 | 1.770 | 264 | 3.520 |
| *Ophiothrix quinquemaculata* | 13 | 0.025 | - | - | - | - |
| *Ophiura texturata* | 21 | 0.025 | - | - | 1984 | 3.550 |
| Total: | 1001 | 5.975 | 599 | 7.980 | 15656 | 25.895 |
| Number of species: | 15 | | 14 | | 18 | |

**B3**

| Station: | | **B3** | **B3** | | **B3** | |
|---|---|---|---|---|---|---|
| Date: | 11.01.88. | 17.10.88. | 08.01.91. | | | |
| Depth (m): | 37 | 37-36 | 39 | | | |
| Species list: | No | kg $h^{-1}$ | No | kg $h^{-1}$ | No | kg $h^{-1}$ |
| *Suberites carnosus* | 11 | 0.605 | 27 | 2.025 | 7 | 0.280 |
| *Cliona celata* | 1 | 0.270 | 5 | 1.875 | - | - |
| *Virgularia mirabilis* | 14 | 0.035 | 107 | 0.265 | - | - |
| *Aphrodita aculeata* | 1 | 0.050 | 21 | 0.785 | - | - |
| *Sternaspis scutata* | 20 | 0.010 | - | - | - | - |
| *Nephrops norvegicus* | 2 | 0.190 | 22 | 1.335 | - | - |
| *Jaxea nocturna* | - | - | 3 | 0.005 | - | - |
| *Paguristes oculatus* | - | - | 28 | 0.070 | - | - |
| *Pagurus variabilis* | 3 | 0.025 | - | - | - | - |
| *Pagurus sp.* | 229 | 0.185 | 104 | 0.055 | - | - |
| *Macropodia rostrata* | 6 | 0.005 | - | - | - | - |
| *Inachus dorsettensis* | 13 | 0.015 | - | - | - | - |
| *Liocarcinus depurator* | 7 | 0.195 | 43 | 0.945 | 1895 | 31.135 |
| *Alpheus glaber* | 11 | 0.020 | 31 | 0.025 | - | - |
| *Pilumnus hirtellus* | - | - | 3 | 0.010 | - | - |
| *Turritella communis* | 99 | 0.120 | - | - | 181 | 0.250 |
| *Fusinus rostratus* | 21 | 0.090 | 9 | 0.030 | - | - |
| *Philine aperta* | - | - | - | - | 1800 | 4.175 |
| *Pinna pectinata* | 4 | 1.200 | 5 | 1.750 | - | - |
| *Chlamys opercularis* | 3 | 0.050 | 32 | 0.587 | 114 | 0.950 |
| *Ostrea edulis* | 1 | 0.120 | 3 | 0.540 | - | - |
| *Pecten jacobaeus* | 1 | 0.035 | 2 | 0.350 | - | - |
| *Anomia ephippium* | 24 | 0.090 | - | - | - | - |
| *Cardium paucicostatum* | - | - | - | - | 6 | 0.010 |
| *Laevicardium oblongum* | - | - | - | - | 1 | 0.010 |

*Table 3. cont'd*

| | | | | | | |
|---|---|---|---|---|---|---|
| *Aloidis gibba* | 85 | 0.050 | - | - | 170 | 0.030 |
| *Cucumaria tergestina* | 3 | 0.005 | - | - | - | - |
| *Cucumaria planci* | 91 | 2.140 | 91 | 2.140 | - | - |
| *Brissopsis lyrifera* | - | - | 24 | 1.200 | - | - |
| *Astropecten irregularis* | 20 | 0.200 | 139 | 1.735 | 84 | 0.065 |
| *Ophiothrix quinquemaculata* | 11 | 0.010 | - | - | - | - |
| *Ophiura texturata* | 18 | 0.015 | - | - | 220 | 0.095 |
| Total: | 751 | 6.450 | 699 | 15.725 | 4478 | 37.000 |
| Number of species: | 25 | | 19 | | 10 | |

**B4**

| Station: | **B4** | | **B4** | | **B4** | |
|---|---|---|---|---|---|---|
| Date: | 11.01.88. | | 17.10.88. | | 08.01.91. | |
| Depth (m): | 42 | | 41-39.5 | | 43 | |
| Species list: | No | kg $h^{-1}$ | No | kg $h^{-1}$ | No | kg $h^{-1}$ |
| *Suberites domuncula* | 40 | 1.400 | 10 | 0.300 | - | - |
| *Suberites carnosus* | - | - | - | - | - | - |
| *Cliona celata* | 3 | 0.540 | - | - | 104 | 7.015 |
| *Aphrodita aculeata* | 60 | 0.865 | 10 | 0.105 | - | - |
| *Squilla mantis* | - | - | 1 | 0.010 | - | - |
| *Processa canaliculata* | - | - | - | - | 16 | 0.010 |
| *Pontocaris cataphracta* | - | - | - | - | 7 | 0.010 |
| *Nephrops norvegicus* | 1 | 0.020 | 12 | 0.615 | - | - |
| *Maia squinado* | - | - | 1 | 0.400 | - | - |
| *Paguristes oculatus* | 17 | 0.035 | 10 | 0.020 | - | - |
| *Pagurus sp.* | 187 | 0.150 | 50 | 0.025 | - | - |
| *Pagurus prideaux* | - | - | - | - | 72 | 0.200 |
| *Macropodia rostrata* | 20 | 0.020 | 40 | 0.050 | 160 | 0.080 |
| *Inachus dorsettensis* | 63 | 0.100 | 60 | 0.100 | 200 | 0.280 |
| *Ethusa mascarone* | - | - | - | - | 13 | 0.010 |
| *Liocarcinus depurator* | - | - | 3980 | 45.000 | 16 | 0.120 |
| *Calliostoma granulatus* | 1 | 0.005 | 1 | 0.005 | - | - |
| *Fusinus rostratus* | 70 | 0.185 | 50 | 0.200 | - | - |
| *Philine aperta* | 12 | 0.045 | 80 | 0.300 | 144 | 0.120 |
| *Scaphander lignarius* | 3 | 0.105 | - | - | - | - |
| *Pinna pectinata* | 7 | 1.400 | 9 | 2.050 | 8 | 1.760 |
| *Chlamys opercularis* | 53 | 1.115 | 30 | 0.900 | 5816 | 45.190 |
| *Pecten jacobaeus* | 1 | 0.030 | - | - | - | - |
| *Ostrea edulis* | 3 | 0.180 | 5 | 0.320 | - | - |
| *Laevicardium oblongum* | - | - | - | - | 1 | 0.040 |
| *Cardium aculeatum* | - | - | 2 | 0.080 | - | - |
| *Venerupis rhomboides* | - | - | 1 | 0.030 | - | - |
| *Aloidis gibba* | 130 | 0.065 | - | - | - | - |
| *Holothuria forskali* | - | - | - | - | 1 | 0.020 |
| *Holothuria tubulosa* | - | - | - | - | 1 | 0.120 |
| *Cucumaria planci* | 320 | 6.335 | 270 | 4.200 | 40 | 0.560 |
| *Echinus acutus* | 1 | 0.250 | 1 | 0.270 | 1 | 0.200 |
| *Psammechinus microtuberculatus* | 10 | 0.100 | - | - | 16 | 0.200 |

*Table 3. cont'd*

| | | | | | | |
|---|---|---|---|---|---|---|
| *Echinaster sepositus* | - | - | - | - | 1 | 0.015 |
| *Astropecten irregularis* | 60 | 0.300 | 40 | 0.200 | - | - |
| *Ophiothrix quinquemaculata* | 21 | 0.020 | 70 | 0.050 | 320 | 0.360 |
| *Ophiura texturata* | 52 | 0.035 | - | - | 208 | 0.320 |
| *Phallusia mammilata* | 3 | 0.480 | 7 | 0.805 | 8 | 0.760 |
| *Styela sp.* | - | - | - | - | 40 | 0.120 |
| Total: | 1138 | 13.780 | 4740 | 56.035 | 7193 | 57.510 |
| Number of species: | 24 | | 23 | | 22 | |